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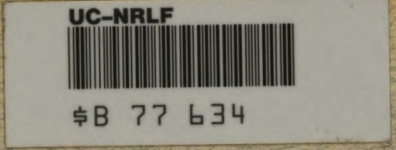

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COOPERATIVE INVESTIGATIONS IN CALIFORNIA

U. S. RECLAMATION SERVICE IN COOPERATION WITH THE
NORTHERN CALIFORNIA IRRIGATION ASSOCIATION

REPORT ON

LOWER PIT RIVER PROJECT

U.S. Bureau of
Reclamation

PREPARED UNDER THE DIRECTION OF THE
PORTLAND OFFICE OF THE U. S. RECLAMATION SERVICE

E. G. HOPSON, Supervising Engineer
T. H. MEANS, Engineer

JULY, 1915

WASHINGTON
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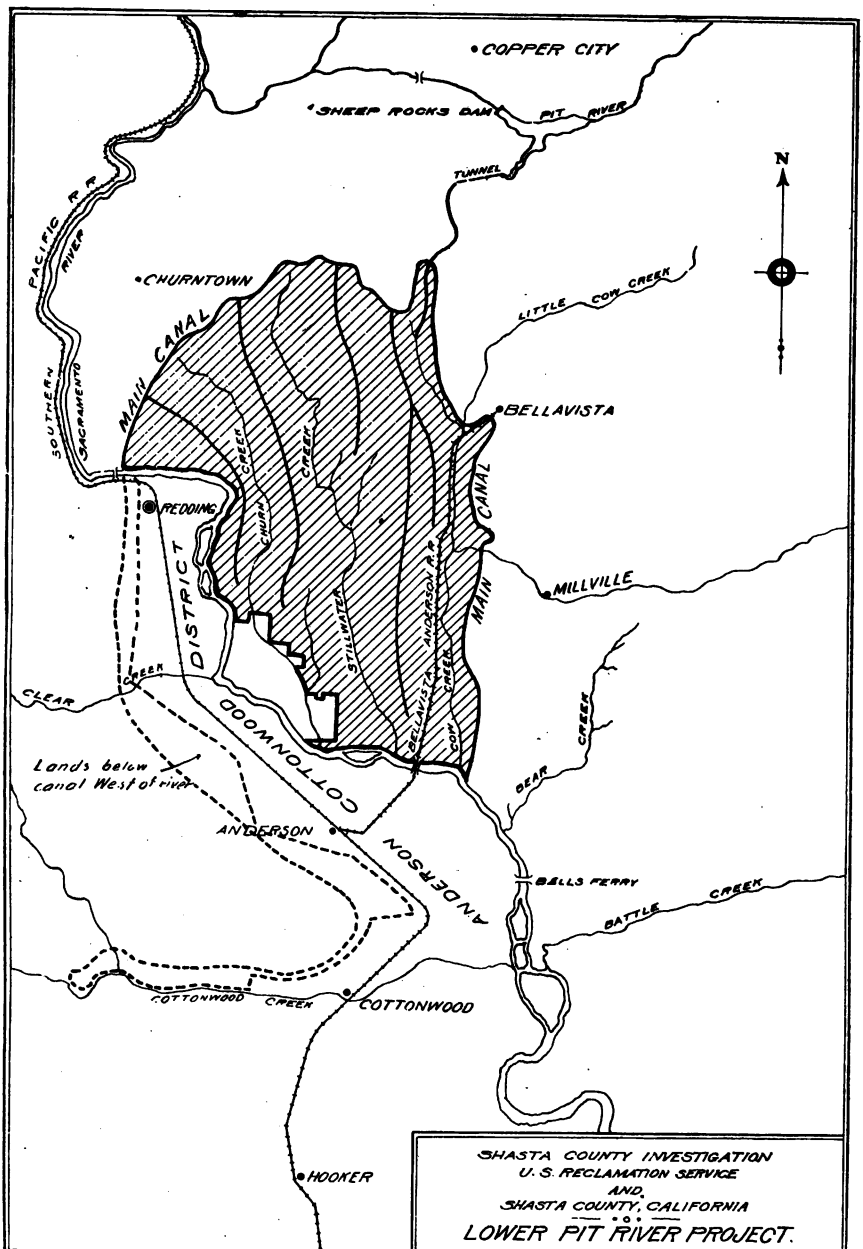

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REPORT ON LOWER PIT RIVER PROJECT.

INTRODUCTION, HISTORY, AND DESCRIPTION.

The following report on the Lower Pit River project has been made by the Portland office of the United States Reclamation Service pursuant to an agreement dated September 10, 1914, between E. G. Hopson, supervising engineer, United States Reclamation Service, representing the Secretary of the Interior, and the Northern California Irrigation Association, through its president, M. T. Howell, and secretary, Roscoe J. Anderson. The Northern California Irrigation Association is an organization of landowners, residents, county authorities, and others interested in development by irrigation of lands in the Sacramento Valley in and in the vicinity of Shasta County.

The particular project herein discussed contemplates the irrigation of about 55,000 acres lying east of the Sacramento River and east and northeast of the city of Redding. It is only recently that the irrigation of this tract of land as a whole has been seriously considered, although in a number of small cases water from the numerous foothill streams has been used for irrigating individual farms. In 1913 and in the spring of 1914 the plan of taking water from the Pit River by means of a high diverting dam and tunnel piercing the ridge that divides the Pit River Basin from those of the small eastern tributary streams of the Sacramento lying immediately to the south was worked into a definite proposition, and a preliminary estimate was prepared by private engineers for the use of interested parties of Shasta County. The plan then proposed contemplated the use of storage reservoirs on the upper Pit to supplement the low-water flow of that stream, in order that diversions for irrigation would not diminish the volume of the low-water flow of the Sacramento River, which below Red Bluff is used for navigation.

Other plans of development have been tentatively considered, largely in connection with projected power projects on Pit River, but nothing really tangible and definite had been worked out, and a great deal of doubt existed as to the extent of the project lands and their value from the agricultural standpoint.

An investigation of the Iron Canyon project, made by the United States Reclamation Service in cooperation with the Iron Canyon Project Association, was completed, and a report published in

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October, 1914. This report deals with irrigation possibilities for Sacramento Valley lands lying a few miles south of the project herein considered. The plans for this project involve a very considerable utilization of the water of the Sacramento River for irrigation, power development, and storage.

Another cooperative investigation by the United States Reclamation Service and the State of California was commenced in 1914 and completed in April, 1915. Various irrigation projects were examined along the upper Pit and a number of reservoirs located and considered in relation to their availability for use. The general conclusions indicate that storage on the upper Pit will be principally useful for local development and of little direct importance to irrigators along the Sacramento below the mouth of the Pit.

The agreement between the United States and the Northern California Irrigation Association, above referred to, is as follows:

"This agreement, made this 10th day of September, 1914, between the United States of America, hereinafter styled the United States, by E. G. Hopson, supervising engineer, United States Reclamation Service, thereunto duly authorized by and subject to the approval of the Director of the United States Reclamation Service and the Northern California Irrigation Association, a corporation duly incorporated under the laws of the State of California, hereinafter styled the association, witnesseth, That—

"Whereas the United States, pursuant to the act of June 17, 1902 (32 Stat., 388), and acts amendatory thereof and supplementary thereto, has at various times made surveys and investigations of irrigation and other projects within the watershed of the upper Sacramento River and the Pit River in northern California, and has caused to be withdrawn from entry and settlement certain public lands of the United States in or in the vicinity of said projects and the reservoirs appurtenant thereto, and has performed other acts with the view of determining and furthering the utilization of the natural resources of the upper Sacramento River and of the Pit River for the benefit of irrigable lands within the drainage areas of said rivers; and

"Whereas by agreement between the United States and the State of California, approved by F. H. Newell, Director of the United States Reclamation Service, June 11, 1914, it is proposed to investigate certain proposed reservoirs and other works within the Pit River watershed, to determine their feasibility and appropriate use, and other matters appurtenant thereto; and

"Whereas the county authorities in Shasta County, Cal., have subscribed certain sums of money for the purpose of making a complete investigation of water storage possibilities of the upper Sacramento and Pit Rivers in order to further the development of irrigation within said county and portions of such other counties as may be dependent thereon or incident thereto, the said sums of money to be expended in such manner as the association may see fit: and

"Whereas the association, which comprises landowners, business men, residents, and other interested parties, principally within the county of Shasta, proposes to use said certain sums of money thus

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subscribed to extend and supplement, if necessary, the investigation provided for in said agreement between the United States and the State of California, approved June 11, 1914, aforesaid, to the end that special attention will be given to irrigation possibilities in Shasta County and the utilization of Pit River waters therein:

"Now, therefore, in consideration of the premises and the mutual covenants herein contained, it is stipulated and agreed between the parties hereto as follows:

"1. That surveys and investigations be made in that portion of the State of California within the watershed of the Sacramento and Pit Rivers to determine the feasibility of constructing reservoirs and other works necessary or desirable for the full utilization of the waters of the Sacramento and Pit Rivers in developing and furthering irrigation within the county of Shasta and such portions of other counties as may be dependent thereon or incidental thereto; also to determine the most advantageous utilization of the public lands, natural lakes, reservoir sites, waters, and other resources of the State and Nation within the said drainage areas as may be related to said purpose.

"2. That the United States, subject to the provisions of this agreement, under which each party shall contribute one-half the cost of the work provided for herein, will perform the necessary surveys and investigations in the field and will prepare designs and estimates of the cost and do such other work as is incident or related to such investigations; that for this purpose the United States will employ the necessary engineers or other assistants and secure and furnish the necessary equipment, instruments, and other appliances for performing the work provided for in this agreement.

"3. That upon completion of the work provided for herein, all of the original plans, notebooks, calculations, and other data prepared and acquired in pursuance of this agreement, shall be filed with the United States Reclamation Service, and the association may have access to and make use of the same for all proper purposes, under reasonable regulations as to their care and preservation.

"4. That prior to or during the prosecution of the surveys and investigations hereunder, and for the purpose of preventing the attachment of rights to the public land within and to the water supply for the projects to be investigated hereunder which may interfere with their development, the Secretary of the Interior will take such action as is authorized by law and in his judgment and discretion may be deemed advisable.

"5. That in carrying out the work hereunder one-half of the expense shall be borne by the United States and one-half by the association, the total expense incurred not to exceed the sum of $5,000, this sum to include all indirect or overhead charges of the United States for admisistrative purposes; that the United States during the progress of the work will furnish the association each month with an estimate of the expenditures to be incurred during the next ensuing month, and the association upon the receipt of each of said estimates shall promptly pay to the special fiscal agent of the United States Reclamation Service at Portland, Oreg., or to such other officer of the United States as may be designated by the Secretary of the Interior, a sum equal to half the amount named in such estimate, it being expressly agreed that such payment by the

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association shall in all cases be made on or before the 15th of the month next ensuing after the presentation of such estimate.

"6. That the United States will also furnish the association each month an itemized schedule of expenditures made pursuant to this agreement for the preceding month, to the end that in case such expenditures do not exactly correspond with the estimates appropriate adjustments can be made from time to time during the progress of the work by way of additions to or the extension of credits in the monthly estimates of future expenditures hereinabove provided for or by way of payments of balance due, so that at the conclusion of the undertaking the proportion of cost borne by each party shall be equal.

"7. Upon the failure of the association to make payment as in this instrument provided, this agreement, at the option of the United States, may be canceled and the work provided for herein stopped, all rights of action for the breach of this contract and for such sums as may be due hereunder for work performed or amounts expended being reserved to the United States.

"8. No Member of or Delegate to Congress, or Resident Commissioner, after his election or appointment, or either before or after he has qualified and during his continuance in office, and no officer, agent, or employee of the Government shall be admitted to any share or part of this contract or agreement, or to any benefit to arise thereupon. Nothing, however, herein contained shall be construed to extend to any incorporated company, where such contract or agreement is made for the general benefit of such incorporation or company, as provided in section 116 of the act of Congress approved March 4, 1909 (35 Stat. L., 1109).

"IN WITNESS WHEREOF the United States Government has caused these presents to be executed by E. G. Hopson, supervising engineer of the United States Reclamation Service, and the association, by resolution of its board of directors, has caused these presents to be subscribed by its president and secretary and its corporate name and seal to be affixed thereto the day and year first above written.

"E. G. HOPSON,

"*Supervising Engineer, United States Reclamation Service,*

"*for and on behalf of the United States of America.*

"THE NORTHERN CALIFORNIA IRRIGATION ASSOCIATION,

"By M. T. HOWELL, *President.*

"Attest: ROSCOE J. ANDERSON, *Secretary.*

"Approved: February 2, 1915."

Attention is directed to the wording of the agreement to the effect that it proposes—

"to extend and supplement, if necessary, the investigation provided for in said agreement between the United States and the State of California approved June 11, 1914, aforesaid, to the end that special attention will be given to irrigation possibilities in Shasta County and the utilization of Pit River waters therein."

The investigation provided for in the agreement of June 11, 1914, was completed and the results embodied in a report entitled "Report on Pit River Basin," dated April, 1915. This report deals

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comprehensively with reservoir possibilities on the Pit River in connection with irrigation development within the Pit River Basin itself and on the Sacramento River. Various important conclusions and recommendations incident to this investigation have been agreed upon between the representatives of the United States Reclamation Service and the State of California and are embodied in the report. At the time of writing this report the report on Pit River Basin is in process of publication; the data contained in the latter have, however, been available for use in the preparation of this report.

The investigations of the upper Pit as disclosed in report of April, 1915, clearly point to the self-contained and independent character of the resources both of land and water along the upper Pit whereby the development of that region may proceed without reference to or interference with that along the lower river. The large storage possibility near Fall River Mills is apparently the only feature of development that may at some future time affect lower river interests. This reservoir may be built of a capacity of approximately 1,000,000 acre-feet and be available for irrigation uses in the Sacramento Valley or possibly as an adjunct for navigation or power purposes. It is, however, unlikely to be needed for development until irrigation uses on the lower river have very seriously depleted the flow of the Sacramento, a condition that will hardly arise during the present generation, and it will be of no importance to the Lower Pit River project.

Pursuant to the provisions of the agreement of September 10, 1914, with the Northern California Irrigation Association, a field force was organized in April, 1915, and field operations and office studies have been carried on concurrently since that date. Mr. Thomas H. Means, agricultural engineer, of San Francisco, has personally directed operations in the field and office, being assisted by Mr. R. A. Edwards, engineer; Mr. W. S. Gillett, soil specialist; and Mr. C. L. Wilbur. All operations have been under the general direction of Mr. E. G. Hopson, supervising engineer, United States Reclamation Service, at Portland, Oreg.

The Northern California Irrigation Association is an incorporated committee of the Shasta County Promotion and Development Association. The officers of the irrigation association are:

M. T. Howell, president.
A. J. Shields, vice president.
Roscoe J. Anderson, secretary.
W. C. Barkuloo, treasurer.

The officers of the Shasta County Promotion and Development Association are:

Dudley V. Saeltzer, president.
Judge Francis Carr, vice president.

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E. L. Young, vice president.
John B. Wallace, vice president.
J. L. Bass, vice president.
Ross Flintjer, vice president.
N. B. Frisbie, treasurer.
Roscoe J. Anderson, secretary.

It is understood that funds for the work contributed by the association were mainly derived from appropriation by Shasta County by vote of the supervisors. Names of supervisors are:

Jos. R. Hunt, chairman.
Fred Hurst.
W. W. Sublett.
William Welsh.
Charles Spann.

THE PROJECT.

Description.—The region examined lies at the head of the Sacramento Valley in California. Redding, the county seat of Shasta County, lies a few miles west of the center of the district. The main lines of the Southern Pacific Railroad from San Francisco to Portland, Oreg., run for 20 miles through the area. About 10 miles north of Redding the upper Sacramento and the Pit River unite, forming the main Sacramento River.

The region along the upper tributaries is mountainous, there being no irrigation of any magnitude possible along either of the streams above this point for many miles. The Pit River drains a portion of the country east of the Sierra Nevada Mountains, breaking through that mountain chain about 50 miles east of Redding. Pit River is the only stream which drains any portion of California through the Sierras into the Pacific Ocean. The mountain range on the south side of Pit River extends for a distance of 5 or 10 miles south of that stream and then breaks off into level or gently rolling lands, timber or brush covered, which farther south open out into treeless plains.

On the west side of the Sacramento below Redding a similar bench, 1 to 5 miles wide, extends to the base of the mountains which bound the valley on the west. This bench originally covered all of the north end of the Sacramento Valley, but has been carved by the Sacramento and tributary streams into a series of rolling benches with narrow margins of bottom land along the streams.

On the east the slope rises to the base of Mount Lassen, 40 miles away.

The topography of this region is shown on the Redding and Red Bluff topographic sheets of the United States Geological Survey.

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Geology.—That portion of the valley covered by the Redding topographic sheet has been mapped by the geologic branch of the Geological Survey and a report has been issued thereon in the Redding folio.

A great variety of geological formations are found in the mountains surrounding this district, mainly of volcanic or intrusive rocks. These rocks furnish the material which composes the unconsolidated sediments and soils of the plains and bottom lands.

The central portion of the irrigable area is made up entirely of sedimentary materials, brought down by the Sacramento River and its side streams. This material is derived from a great variety of rocks and is generally suitable for making a good soil. It is characteristically abundant in iron, as indicated by the general red color of all of the soil. This iron no doubt comes from the large amount of volcanic rocks in the Mount Lassen region.

The mountains which surround the head of the Sacramento Valley are rich in minerals and a number of mining camps are well established.

Climate.—This district has the climate typical of the interior valleys of California. Summers are long and hot, with dry atmosphere and very little rain; winters are mild, with an abundance of rain from October until April. The rainfall in the north end of the valley close to the mountains and on the mountain slopes is greater than in other parts of the valley. The rainfall at Redding is, however, representative of the irrigable part of the project.

The following table gives the mean monthly rainfall at Redding and, for comparison, at three other stations in the central valley. It will be seen that the rainfall at Redding is heavier than at other places in the valley, but that the months of June, July, August, and September are nearly rainless.

Seasonal rainfall.

Month.	Redding.	Orland.	Sacramento.	Fresno.
	Inches.	*Inches.*	*Inches.*	*Inches.*
July	0.09	0.01	0.02	T.
August	.07	.02	.01	T.
September	.78	.40	.23	0.29
October	2.42	1.06	.85	.63
November	4.17	2.21	2.08	1.13
December	6.54	2.90	4.04	1.47
January	7.77	3.54	3.85	1.71
February	5.57	2.93	2.94	1.36
March	5.38	2.65	2.98	1.81
April	2.96	1.24	1.62	.97
May	2.24	.93	.82	.56
June	.73	.34	.13	.11
Year	36.13	18.48	19.56	10.04

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The temperature at Redding does not differ so much from the temperatures at other places in the valley as does the rainfall. The following table shows that the average temperature compares closely with that at Orland and Fresno. The temperature at Sacramento is lower than that of the rest of the valley on account of the influence of the winds from San Francisco Bay:

Mean monthly temperatures.

Month.	Redding.	Orland.	Sacramento.	Fresno.
	° F.	° F.	° F.	° F.
January	45.2	47.6	45.6	45.4
February	49.3	51.2	50.2	49.2
March	53.8	58.7	54.2	54.9
April	60.2	63.4	58.0	61.2
May	67.2	70.4	62.9	68.4
June	75.6	78.7	68.9	75.8
July	82.3	86.4	72.5	82.0
August	81.0	84.2	72.1	81.2
September	74.0	76.7	69.1	74.3
October	64.5	66.4	62.2	64.7
November	54.1	56.4	53.4	54.6
December	47.0	47.9	46.3	46.8
Year	62.8	65.4	59.6	63.2

From the standpoint of agriculture in California the frost question is of first importance. The Weather Bureau reports show the average date of last frost in spring about March 5 and the first in fall November 23. Redding is typical of the entire project. Minimum temperatures seldom go below 20° F. The lowest ever recorded was 18° F. The climate is mild enough for the production of oranges, though there are no commercial growers in the neighborhood. Orange trees which are 15 years old are found at various points in the valley, indicating that no severe winters have been experienced in that period. Olives, which can stand light frosts, are found in all parts of the district. This is another indication of the mildness of the climate.

Storms of heavy rainfall happen during the winter months. These are not harmful to vegetation if slopes are protected from erosion. Irrigation canals must be protected by ample culverts and spillways to handle these storm waters.

It may be said, in brief, that climatic conditions are so similar to those of the entire central valley of California that all classes of crops grown in that valley can be produced around Redding.

Irrigable area.—The study of the irrigation possibilities of the Lower Pit River project show that a dam and tunnel can be built to deliver water to the south side of the mountains which border the river at an elevation of from 825 to 875 feet. The topography of the country makes it clear that it is not possible to economically carry the canal at any greater elevation. The study was therefore

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confined to the area below the 900-foot contour. From this gross area of about 100,000 acres has been deducted such areas as were assumed nonirrigable from their location, soil, or any other reason. An area of 30,000 acres has also been left out of consideration, as it is already organized into the Anderson-Cottonwood district, and provision is now being made for its irrigation by a canal from the Sacramento River with diversion at Redding.

The map, plate 1, shows the area regarded as irrigable.

In order to determine with as great a degree of accuracy as possible the net area irrigable, an examination independent of the soil survey was made of the area below the canal lines. This examination was made to determine the area irrigable from the standpoint of slope and roughness.

The lands were classified as being of three characters:

The No. 1 classification covers those lands which would lend themselves readily to irrigation with very little expenditure of preparation. It is not intended, however, that such lands are all adaptable to forage crop irrigation, for under this classification are some lands which, although adapted to horticultural irrigation, have too great slopes to be readily watered for forage crops.

The No. 2 classification covers that acreage which is broken by washes and, although well adapted to tree and vine culture, would require some initial expenditure to be made irrigable.

The No. 3 classification covers those lands that were not considered irrigable either from steep slope or roughness or because they are above the flow line of the laterals.

Within the time and expenditure allowed it was impossible to classify these lands in distinct sectional areas, and these determinations throughout were made on a percentage basis; that is, a given district would be classified as being composed of a certain percentage of No. 1, a certain percentage of No. 2, and a certain percentage of No. 3 lands. Upon this basis there are 59,200 acres of irrigable land in classes 1 and 2. Of this acreage 4,000 have been found to be of no agricultural value; the total irrigable area therefore has been taken as 55,000 acres.

Pumping possibilities.—There are some small tracts of land which lie above the supply canal to which water could be pumped at a reasonable cost. It was not possible, however, to investigate these isolated tracts in the time available for the survey.

Ownership.—Nearly all of the land within the limits of the project is in private ownership; only a few odd pieces are owned by the Government. From about a quarter to a third of the irrigable lands are owned by the Central Pacific Railway Co. The railway lands are confined to the northerly portion of the project. Of the balance of the irrigable area holdings are generally of less than 640 acres in extent.

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IRRIGATION SYSTEM.

General outline.—The proposed project provides for a dam in Pit River at Sheep Rocks, one-half mile above the mouth of Squaw Creek, or 8 miles above the mouth of Pit River. This dam will be about 136 feet high, measured from its top to the water surface of the river, and will raise the water 126 feet, or to elevation 902 feet above sea level. This dam will permit water to be diverted into a tunnel 13,000 feet long from a point in the upper part of Clikapudi Creek into Dry Creek, on the south side of the mountain ridge separating the Pit and Sacramento Basins. From the lower portal of this tunnel the water will be carried westward by a canal skirting the foothills and supplying laterals to irrigate land to the southward. It is physically possible to extend this canal to the Sacramento River, and by crossing at a point about 1½ miles from Redding to irrigate the lands directly west of that city. It is also physically possible to extend this canal southward along this bench, across Clear Creek, and into Cottonwood Creek bottoms. The canal would reach Cottonwood Creek at an elevation of approximately 550 feet, and this elevation would permit of even further extensions southward toward Red Bluff. Economic considerations, however, entirely preclude such extensions by reason of the long and costly work involved.

The laterals on the east side of the Sacramento River would follow down the ridges of which this country is formed, covering the area between Cow Creek on the east and the Sacramento River on the west. Between these laterals, sublaterals would form a network supplying the entire area.

Duty of water.—The rainfall at Redding averages about 39 inches a year, and were this rainfall distributed more uniformly throughout the season the necessity for irrigation would be much less. The period between April and October is too dry for crops, particularly the months of June, July, and August. Irrigation therefore becomes a necessity during these months if maximum crops are to be expected.

There is no definite information concerning the minimum amount of water which would be desirable in this neighborhood, as no duty of water experiments have been made, so it is assumed that the same quantity of water would be required as at Orland. On the Orland project irrigation has been carried on for a length of time sufficient to make the records interesting and valuable. At Orland the rainfall is 18 inches, or about one-half the rainfall at Redding. At Orland 3 acre-feet of water per acre of land is regarded as sufficient on the average. It may be assumed that this amount will

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be sufficient at Redding; and for the purpose of estimate made in this report this figure has been accepted.

The heaviest use of water will be during the months of May, June, and July, and it would seem that a canal should be designed of sufficient capacity to deliver between 20 per cent and 25 per cent of the 3 acre-feet of water during any one month of 30 days. Upon this basis, when canals are designed with capacity to discharge 1 cubic foot per second for each 100 acres of land, ample water for irrigation during the dry months can be delivered. The following table shows the duty of water at Orland:

Duty of water at canal head.

Month.	Per cent per month.	Acre-feet per acre.	Month.	Per cent per month.	Acre-feet per acre.
March	5.7	0.17	September	7.0	0.21
April	9.6	.29	October	2.0	.06
May	14.0	.42	November	2.0	.06
June	18.9	.57			
July	21.9	.66		100.0	3.00
August	18.9	.56			

Lateral canals should be designed for a higher delivery. For the purpose of this estimate lateral canals have been estimated at 1 second-foot per 60 acres of irrigable land.

As no doubt a large portion of the Lower Pit River project will be devoted to the growing of fruit crops, which will be irrigated by the furrow method, delivery of water will be in comparatively small heads. It is difficult to handle large quantities of water where the furrow method of irrigation is used and where the land is rolling in contour. In such places water is delivered in smaller heads, but for longer periods of time to each irrigation.

Water supply.—Three possible sources of water supply for the project were investigated: The Sacramento River, the larger creeks which empty into the Sacramento River from both sides of the valley, and the Pit River.

The Sacramento River might occur at first thought to be the logical source of water supply for the area under consideration. There are, however, some serious disadvantages in using this supply. The greatest disadvantage would be the necessary reconstruction of the roadbed of the Southern Pacific Railroad Co. The present location of the company's line is just above the high-water mark of the river for a distance of 50 miles above Redding. The town of Kennett is also located just above the high stage of the river and would be submerged should a dam be built to afford diversion at elevation 700. This elevation (700) was found to be the maximum afforded by favorable dam sites on the river at points below Kennett. Further-

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more, a diversion at elevation 700 would not permit the irrigating of a large area of land which lies above this level.

As a source of water supply for the bench lands of Shasta County the Sacramento River is believed impractical for the above reasons.

The larger creeks which flow into the Sacramento River, although perennial, have not sufficient summer flow to be of any great value, but with moderate storage some of these creeks could be made worthy of careful consideration. Storage sites, therefore, were sought of those creeks which offered good possibilities. The following creeks were investigated: Little Cow Creek, Clover Creek, Oak Run Creek, Old Cow Creek, South Cow Creek, Bear Creek, and on the west side of the Sacramento, Clear Creek.

It was not found possible to make an investigation of Cottonwood Creek within the time or funds allowed for this work. The topographical location of this stream is such, however, that it can serve those lands lying within its own lower drainage area. There are probably 12,000 acres which might be watered from the two larger forks of this stream, provided sufficient storage could be procured.

The Pit River with a minimum flow of 2,700 second-feet would appear as the result of these investigations to be the most practical source of supply.

This stream was investigated for dam sites for a distance of 24 miles from its junction with the Sacramento River. This investigation was greatly facilitated by the use of the map and profile of this stream prepared by the California State Water Commission. Cutting the Sierra Nevada Mountains transversely as it does, it might be supposed that this stream would flow through deep box canyons. Through the reach of the river that was investigated, however, this is not the case, and few favorable dam sites were found. The site finally chosen is approximately one and a half miles above the mouth of Squaw Creek, at a point known as Sheep Rocks.

Records of flow of Pit River.—The following table shows the maximum, minimum, and monthly flow of the Pit River at the Ydalpom or Silverthorne gauging station, just below the mouth of Squaw Creek, as given in Water Supply Papers of the United States Geological Survey:

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Month.	Discharge in second-feet.			Month.	Discharge in second-feet.		
	Maximum.	Minimum.	Mean.		Maximum.	Minimum.	Mean.
1910–11.				1912–13.			
Nov. 16–30	4,960	3,120	3,710	October	3,030	2,740	2,810
December	8,960	3,520	5,090	November	7,520	3,030	3,730
January	15,400	3,440	5,410	December	6,360	3,030	3,820
February	17,700	4,620	8,420	January	18,400	3,330	5,490
March	20,600	4,620	12,200	February	4,770	4,100	4,550
April	18,600	7,020	10,600	March	7,520	3,940	5,560
May	10,900	5,300	6,600	April	10,100	5,110	6,980
June	5,300	3,670	4,500	May	5,460	3,780	4,680
July	3,670	3,300	3,550	June	3,940	3,330	3,470
August	3,300	3,080	3,150	July	3,480	3,030	3,170
September	3,080	3,080	3,080	August	3,330	2,740	2,960
				September	2,740	2,740	2,740
1911–12.							
October	3,220	3,080	3,170	1913–14.			
November	3,440	3,150	3,300	October	2,740	2,740	2,740
December	3,220	3,220	3,220	November	6,550	2,740	4,680
January	13,900	3,220	4,760	December	33,900	3,030	4,600
February	6,000	3,820	4,560	January	32,800	8,750	17,500
March	8,120	3,820	5,270	February	31,800	6,000	10,500
April	7,320	3,980	4,440	March	11,500	7,520	9,910
May	8,330	3,980	5,270	April	15,300	7,320	10,100
June	4,620	3,370	3,680	May	7,120	4,600	5,530
July	3,370	2,950	3,140	June	5,280	3,630	4,150
August	2,950	2,830	2,880	July	4,260	3,030	3,470
September	3,820	2,830	3,000	August	3,030	2,740	2,800
				September	2,880	2,740	2,800

In the reports on the Iron Canyon project and the Pit River Basin, previously referred to, there appears a full discussion of the sources of the low-water flows of the Pit River. It is unnecessary to repeat these discussions and statistics, the substance of which is that the low-water flow at the proposed point of diversion, Sheep Rocks, comes mainly from the immense springs at the head of Fall River. These have a combined discharge of from 1,400 to 1,600 second-feet. The next important supply is from the springs that feed Hat Creek, with a minimum of about 700 second-feet, and of Burney Creek with 150 to 200 second-feet. These three sources alone thus contribute more than 2,300 second-feet of spring flow originating in the great lava beds that extend from Lassen on the south to Klamath Lakes on the north. Other large springs from the same source, but individually of lesser size than those above referred to, enter the Pit Canyon at various points and bring the total low-water flow up to 2,740 second-feet, the figures given in the above tabulation.

The dam site selected at Sheep Rocks is above Squaw Creek. This stream has a very low minimum flow; in the late summer the flow drops to 25 cubic feet per second or less, and so far as low flow is concerned does not affect the problem of water supply. The low-water flow of Pit River above Squaw Creek is over four times the amount of water required for the irrigation of 60,000 acres.

Possible development of supply from creeks.—The investigation of those creeks entering the Sacramento below Pit River failed to locate any storage sites worthy of consideration, except on the South

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Fork of Cow Creek. On this stream two sites were found which offered possibilities. In sec. 33, T. 32 N., R. 1 W., a dam approximately 100 feet high and 600 feet long would afford an estimated storage of 15,000 acre-feet. This stored water at elevation 1,400 might be utilized to water some of the higher bench lands on the east side of the valley.

Another site which offers possibilities is located just above the junction of the two forks of Cow Creek, and would no doubt afford a large storage, but the elevation of this supply would be too low to be fully utilized by lands in this project.

Small irrigation projects may be possible of development from some of these creeks without storage, particularly Cow Creek and Clear Creek. Areas of 2,000 to 3,000 acres may thus be economically watered as single units.

The records of flow of these streams by the United States Geological Survey cover only a short period, but serve to give a fair idea of the water supply they might afford.

Monthly discharge of Clear Creek at Shasta, Cal., for 1911–12.

[Estimated drainage area, 180 square miles.]

Month.	Discharge in second-feet.			Run-off (total in acre-feet).
	Maximum.	Minimum.	Mean.	
October	10	10	10.0	615
November	10	10	10.0	595
December	114	10	21.4	1,320
January	2,000	83	267.0	16,400
February	291	103	168.0	9,660
March	1,050	92	391.0	24,000
April	1,450	219	388.0	23,100
May	1,120	254	509.0	31,300
June	436	219	271.0	16,100
July	236	66	98.7	6,070
August	61	34	48.3	2,970
September	254	44	65.8	3,920
The year	2,010	10	187.0	136,000

Monthly discharge of Cow Creek at Millville, Cal., for 1911–12.

[Estimated drainage area, 200 square miles.]

Month.	Discharge in second-feet.			Run-off (total in acre-feet).
	Maximum.	Minimum.	Mean.	
October	153	79	87.7	5,390
November	155	86	103.0	6,130
December	117	86	102.0	6,270
January	2,040	101	290.0	17,800
February	266	101	139.0	8,000
March	1,470	101	263.0	16,200
April	328	117	154.0	9,160
May	416	200	263.0	16,200
June	252	94	141.0	8,390
July	94	47	67.2	4,130
August	59	47	53.5	3,290
September	1,410	53	130.0	7,740
The year	2,040	47	150.0	109,000

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Monthly discharge of Clover Creek at Millville, Cal., for 1911–12.

[Estimated drainage area, 50 square miles.]

Month.	Discharge in second-feet.			Run-off (total in acre-feet).
	Maximum.	Minimum.	Mean.	
October	46	13	15.6	959
November	26	14	17.1	1,020
December	27	17	19.5	1,200
January	677	14	91.4	5,620
February	279	27	55.1	3,170
March	494	20	107.0	6,580
April	99	32	43.6	2,590
May	151	36	63.1	3,880
June	52	10	22.3	1,330
July	12	4	7.5	461
August	6	2	3.0	184
September	312	4	28.0	1,670
The year	677	2	39.4	28,700

Monthly discharge of Little Cow Creek at Palo Cedro, Cal., for 1911–12.

[Estimated drainage area, 150 square miles.]

Month.	Discharge in second-feet.			Run-off (total in acre-feet).
	Maximum.	Minimum.	Mean.	
October	20	11	15.8	972
November	33	18	22.1	1,320
December	26	20	22.7	1,400
January	2,030	20	315.0	19,400
February	1,050	64	226.0	13,000
March	1,390	51	352.0	21,600
April	400	51	119.0	7,080
May	653	72	215.0	13,200
June	226	11	49.4	2,940
July	14	3	5.89	362
August	5	1	3.39	208
September	226	1	18.5	1,100
The year	2,030	1	114.0	82,600

Monthly discharge of Bear Creek near Millville, Cal., for 1911–12.

[Estimated drainage area, 106 square miles.]

Month.	Discharge in second-feet.			Run-off (total in acre-feet).
	Maximum.	Minimum.	Mean.	
1911.				
August 19–31	34	34	34.0	876
September	48	34	39.8	2,370
1911–12.				
October	100	46	56.9	3,500
November	65	60	62.5	3,720
December	65	50	59.2	3,640
January	970	50	135.0	8,300
February	85	47	64.4	3,700
March	620	44	167.0	10,300
April	166	54	81.0	4,820
May	260	16	78.3	4,810
June	59	14	26.2	1,560
July	17	2	5.78	355
August	2	2	2.0	123
September	910	2	82.0	4,880
The year	970	2	68.4	49,700

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Discharge of Oak Run Creek near Millville, Cal. (sec. 3, T. 31 N., R. 3 W.).

[Estimated drainage area, 16 square miles.]

	Second-feet.
Oct. 3, 1910	2.2
May 31, 1912	13.0

Dam site.—The Sheep Rocks dam site has many features which give it preference over other possible sites on the Pit River above this point. The topography here is more favorable than that of the other sites. The feasibility of building a railroad of only 2 miles in length and connecting with the Sacramento Valley & Eastern Railroad Co.'s line at the mouth of Squaw Creek is a marked advantage. Bedrock is shown by the exposure of volcanic tuff over the whole site. Another advantage at this point is the favorable spillway offered at the south end of the dam site. The discharge from the spillway would be into Jones Valley Creek, a small tributary of the Pit. The danger of back wash on the lower toe of the dam would be entirely eliminated, as the water running via Jones Valley Creek would enter the river channel approximately 1,500 feet below the dam site. A topographical survey of this site was made, and detailed map is filed with the exhibits. A small scale plan showing some of the work appears as reduced on plate 3.

Dam.—This as proposed will raise the water from its present normal elevation at 774 to elevation 902, a total rise of 138 feet. The dam will have a crest at elevation 910 and be about 600 feet long, measuring along the crest. It is proposed to excavate a spillway on the left abutment, along a ridge separating the main river valley from Jones Valley Creek, a small tributary entering the river about one-half mile below the dam site. A great mass of material will be removed from the spillway which it is believed will constitute suitable rock filling for the dam. The spillway will have a finished masonry crest at elevation 890 and a width of 300 feet, measured along its crest. Water levels will be controlled by movable gates on the spillway, possibly of the rolling type, in order to pass all flood flows with safety to the dam.

Comparative estimates of cost of three different types of dams for this site indicate as follows:

Gravity masonry type	$1,585,000
Arch masonry type	1,040,000
Rock-fill type	889,000

An earth dam is not feasible, owing to lack of suitable earthy material in the vicinity; moreover, the site does not seem well suited for an earth structure.

While it was not possible in this investigation to make an absolute determination of the most suitable type of dam to be used at this point, all indications beside those of cost point pretty strongly to

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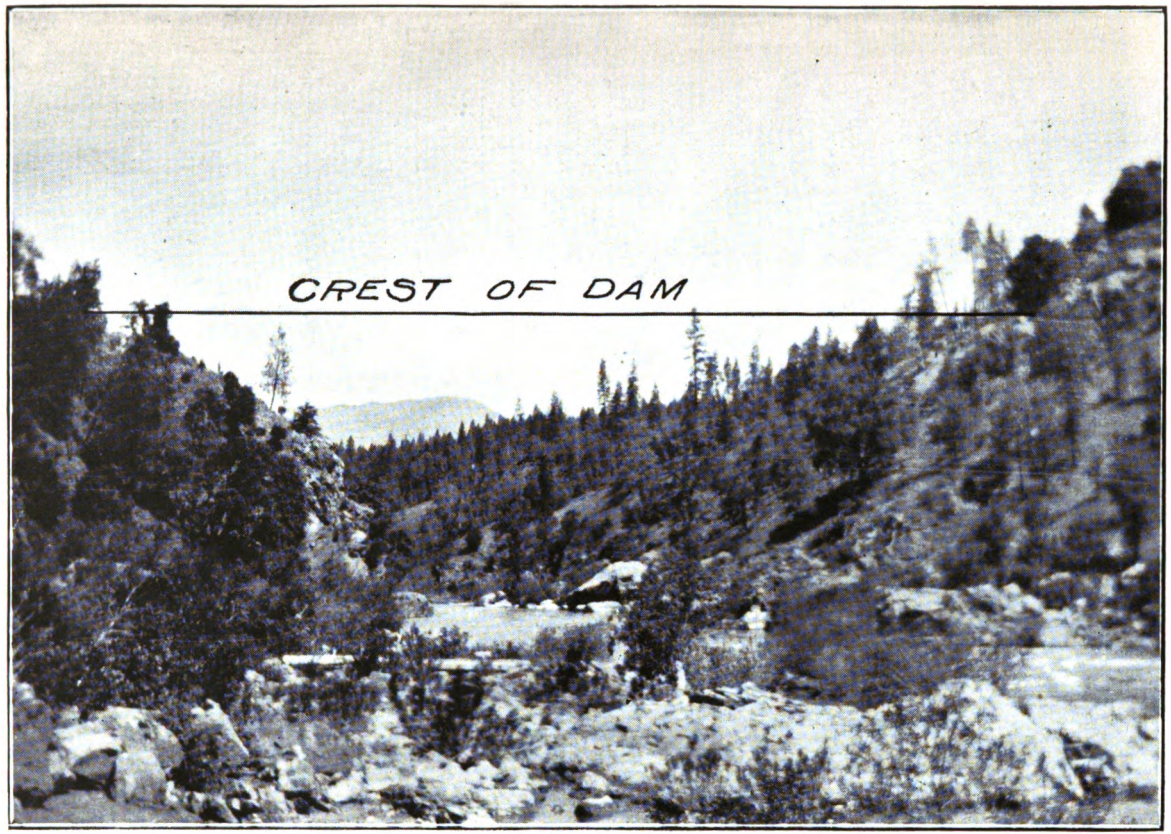

VIEW OF SHEEP ROCKS DAM SITE ON LOWER PIT RIVER.

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the rock-fill type. For purposes of estimate it has been assumed that many feet of material will be excavated from the entire site of the dam prior to the placing of the dam embankment.

With a rock-fill dam the danger from faulty foundation would be reduced to a minimum, since the upward pressure of water on the base of such a dam is relieved by the porous nature of the structure itself, which always permits of ample drainage. Percolation of water through the rock beneath the cut-off wall probably would prove a matter of small consequence unless test borings showed very porous substrata. Outcroppings, however, indicate the continuity of fair rock to a considerable depth.

The greatest recorded flow of Pit River is 33,000 cubic feet per second. In February, 1909, a very large flood passed down the river, but was not measured. A comparison of this flood with measured flows of the Sacramento River at Red Bluff leads to the opinion that the flood at Sheep Rocks did not exceed 40,000 second-feet. The spillway as designed is 900 feet long, and with the gates wide open there would be a depth of 12 feet below elevation 902. This will pass a flood of 42,000 second-feet with the water level still 8 feet below the top of the embankment.

The rock-fill dam as designed is shown on plate 3. Its dimensions are as follows:

Top of rock-fill embankment	elevation 910
Crest of spillway	elevation 890
Present water surface	elevation 774
Maximum height of dam	about 156 feet
Upstream slope	1 to 1
Downstream slope	1 to 1½
Width of crest	20 feet

Concrete facing, 3 feet thick at bottom, 2 feet thick at top.

The proposed method of unwatering the dam site is by means of two 16-foot concrete conduits built just above low water on the north bank of the river and leading to a rock cofferdam above the site to a similar dam at the lower toe of the main structure. These pipes would be similar in design to the 20-foot conduit employed for the same purpose at the Calaveras Dam of the Spring Valley Water Co., in Alameda County, Cal. An alternative method of unwatering the site would be the construction of a tunnel 900 feet long under the south abutment. Such a tunnel probably would prove somewhat cheaper, but the use of powder in its construction might tend to disturb the foundation and result in troublesome leakage through this section.

It is proposed to face the dam with a concrete wall 3 feet thick at the base and 2 feet thick at the top. This wall would rest upon a cut-off wall of concrete about 6 feet thick that would be founded on the more impervious substrata. The concrete facing would be laid

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upon a wall of hand-laid rock composing the upper slope of the dam. The thickness of this wall of dry stone masonry would depend upon quarry tests to determine to what extent the native rock would lend itself to such work. It is believed, however, that a wall 20 feet thick at the base and 10 feet thick at the top would prove ample.

In the Cucharas Dam recently built in Colorado, of practically the same dimensions, the same side slopes have been employed as proposed here. The concrete facing of the former is slightly thinner, and the dry masonry backing somewhat thicker, but on the whole the dimensions are practically the same. The proposed structure also compares very well with the Morena rock-fill dam near San Diego, Cal., built some years ago.

In connection with the matter of dam estimates, the following comparisons may be of service. The dam as proposed will contain about 350,000 cubic yards of embankment material at an estimated cost of about $890,000 for the structure complete. This will give an average cost of little more than $2.50 per cubic yard of embankment, this being an inclusive figure covering all incidentals such as concrete, steel, and other work. Comparing this with the cost of the rock-fill dam at Clear Lake, in Modoc County, Cal., there is at the latter point a total yardage of about 70,000 cubic yards of earth and rock fill. The Clear Lake Dam cost about $110,000, so that the average inclusive price of the dam embankment was about $1.80 per cubic yard. The rock-fill dam at Conconully, Wash., contained about 360,000 cubic yards of earth and rock, the dam complete costing about $350,000, or an average inclusive price of about 90 cents per cubic yard of embankment. The earth dam at Cold Springs Reservoir, Oreg., contains 700,000 cubic yards of embankment, the dam costing $450,000, complete, or a corresponding inclusive cost per cubic yard of 65 cents. The earth dam at Lahontan Reservoir, Nev., contains approximately 1,000,000 cubic yards of material, the dam costing about $1,500,000, the inclusive cost per cubic yard being about $1.50. The Lahontan Dam, however, included very extensive and costly masonry spill ways. It thus appears, by comparison, that in the aggregate the estimate for the Sheep Rocks Dam is higher than the costs of any of the other dams referred to, and may be accepted as reasonably conservative.

Other sites.—The possibility of diverting water from the river with a lower dam at a point farther up the stream does not appear feasible. No dam site presenting possible economies in construction such as the Sheep Rocks site exists; in general there are very few good sites in this canyon due to width and depth of bottom. The cost of canal construction in the canyon would, moreover, be very high, due to the steep and precipitous nature of the side slopes.

Tunnel.—Two locations of a tunnel were investigated. From a point at elevation 900 in Clikapudi Creek Canyon a tunnel 12,000

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feet long would deliver water at elevation 863 in Willow Creek Canyon. This tunnel would be approximately 1,000 feet shorter than a bore connecting points at the same elevation in Clikapudi and Dry Creek Canyons. The latter, however, was finally accepted as being the better location, since it eliminated 3 miles of costly canal construction otherwise necessary. This tunnel is shown in section on plate 3. Its inside dimensions are 8 feet wide and 10 feet high.

Outcroppings along the line show shale and altered rhyolite. No serious difficulties should be encountered in driving this tunnel, though a moderate flow of ground water may be expected.

Two shafts are proposed, each about 300 feet deep, dividing the tunnel into three sections of somewhat unequal length, the longest drive being 5,400 feet. It is probable a more advantageous location of tunnel line and shafts can be made with more extended time and means, but it is improbable a final location will materially alter the dimensions above given.

The hydraulic elements of the tunnel are as follows:

Q —600 second-feet.
A —60.0 square feet.
R —2.69.
N —0.015.
S —0.00271.
V —10.0 feet per second.

In the estimates of cost, allowance has been made for continuous timbering for roof supports. This is mainly by reason of the lack of definite knowledge of the ground. The probabilities are that much timbering would be unnecessary, and the cost of the work would be correspondingly reduced.

Construction supplies could be delivered to the site via a wagon road from the terminus of the proposed railroad at the dam site, 2 miles distant from the north portal, or via wagon road from the present terminus of the Bella Vista & Anderson Railroad, 8 miles distant from the south portal.

In considering the estimates of cost it will be noted that the shafts will probably cost about $1 per foot of tunnel length. Allowance has been made for concrete lining of an average thickness of 12 inches. The tunnel work proposed is estimated at $52 per linear foot. Comparisons with other completed work are as follows:

The Laramie-Poudre Tunnel, in Colorado, has inside dimensions of 7½ by 9½ feet, a capacity of 800 second-feet, and a length of 11,306 feet. These dimensions are very similar to those of the work herein proposed. The rock is a hard granite, necessitating little timbering. Cost of untimbered tunnel was $29.81 per foot; additional cost of timbering averaged $7.05 per foot.

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A tunnel at Iron Mountain, a locality within a few miles of the point under consideration, gave an average cost of tunnel excavation at $4.04 per cubic yard, as compared with $6 per cubic yard allowed in these estimates. The cost of timbering at Iron Mountain was $4.38 per foot, against $7 per foot allowed herein.

The North Fork and Tieton Tunnels, in Washington, circular in shape, with inside diameter of 6 feet, cost for excavation, including timbering, $19.35 per foot; the additional cost of lining with concrete was $8.35 per linear foot.

Main canal.—At the southern portal of the tunnel a small amount of water would be spilled into Dry Creek, to be diverted again at a point 3 miles below, to supply the Dry Creek and Cow Creek laterals. The main canal, of 600 second-feet capacity, leading to the west, would follow closely the foot of the higher mountains and furnish water at a sufficient elevation to irrigate all of the better bench lands lying to the south.

The main canal and larger lateral canals were approximately located with hand instruments and platted on the United States Geological Survey topographical map, 100-foot contour intervals. A section of the main canal was then surveyed with a transit and the actual distance compared with the distance as scaled from the map. With this comparison as a basis the length of canals as scaled from the map was increased accordingly as the country traversed was smooth or broken.

The first 5 miles of the main canal would be of concrete-lined section and almost wholly in rock cut. A concrete lining of 4 inches is provided in the estimates. Plate 4 illustrates canals with concrete linings recently built.

The cloudbursts and heavy rains which occur in this region necessitate the use of heavy construction and large drainage culverts.

At a point 5 miles below the tunnel the laterals begin branching off and the main canal is rapidly diminished in size until at the western end the capacity is 30 second-feet.

The canal in earth section is designed somewhat more shallow than is usually the case in good practice. This is done to avoid deep cutting in the cement gravel and rock which generally lie at a depth of 3 to 4 feet below the ground surface.

Lateral system.—The lateral system is clearly determined by the marked topography of the country, which shows long benches running north and south. The fall of these benches is gradual and uniform. Transversely they are virtually level and well adapted to irrigation, the many streams affording excellent drainage. A lateral canal running down each of these benches will permit of watering practically all of the land as bounded by the defining streams of each bench. Since irrigating heads of 5 second-feet will be used these laterals will be small and easy of construction and maintenance.

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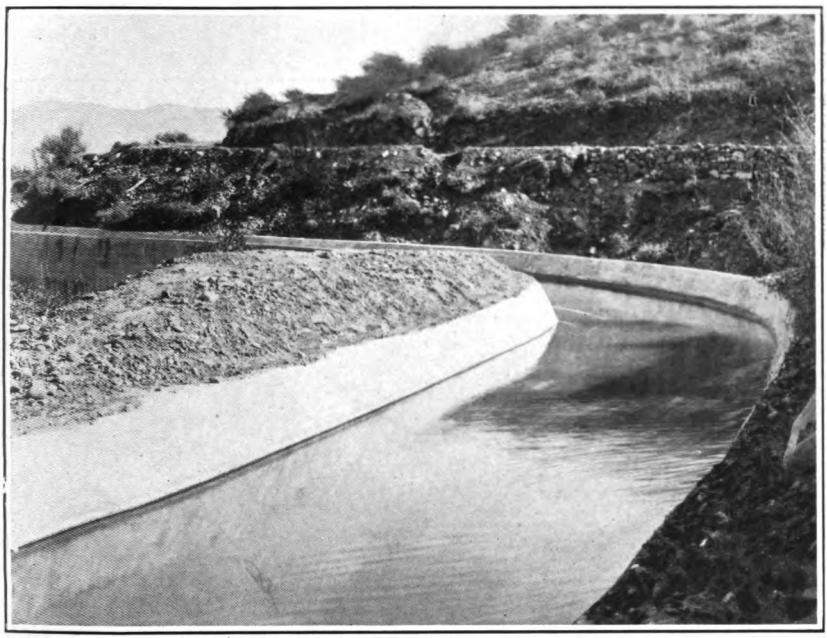
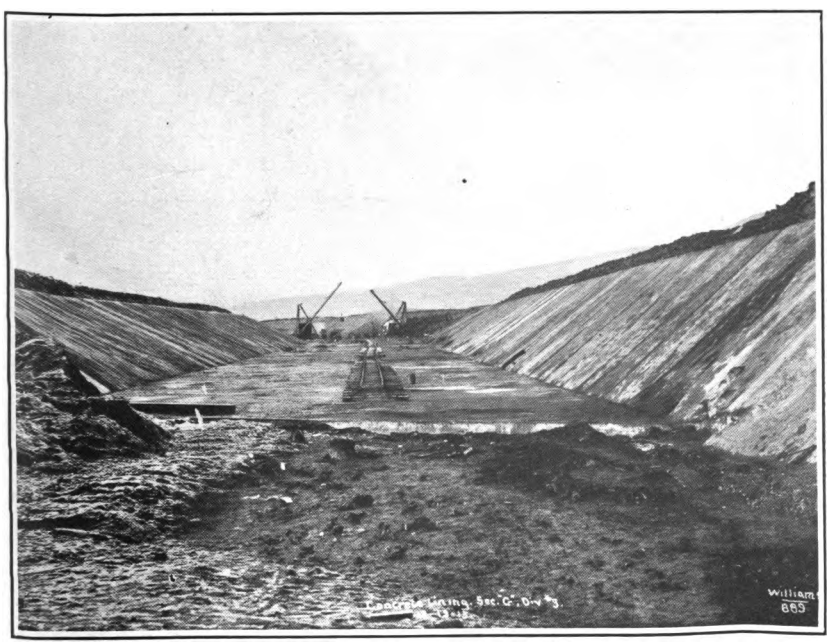


CONCRETE-LINED CANAL BUILT BY U. S. RECLAMATION SERVICE, ROOSEVELT, ARIZ.



LARGE CONCRETE-LINED NAVIGATION CANAL BUILT BY U. S. WAR DEPARTMENT, CELILO, OREG.

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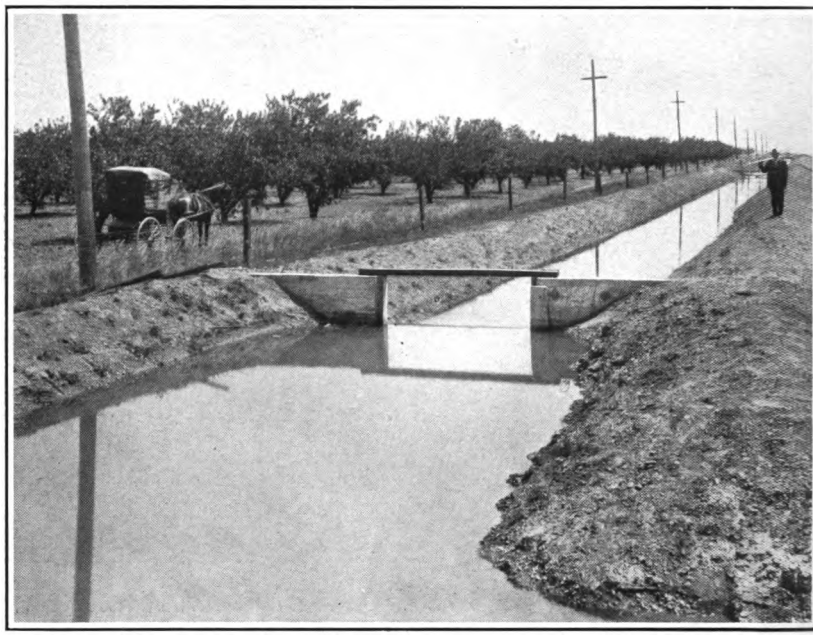

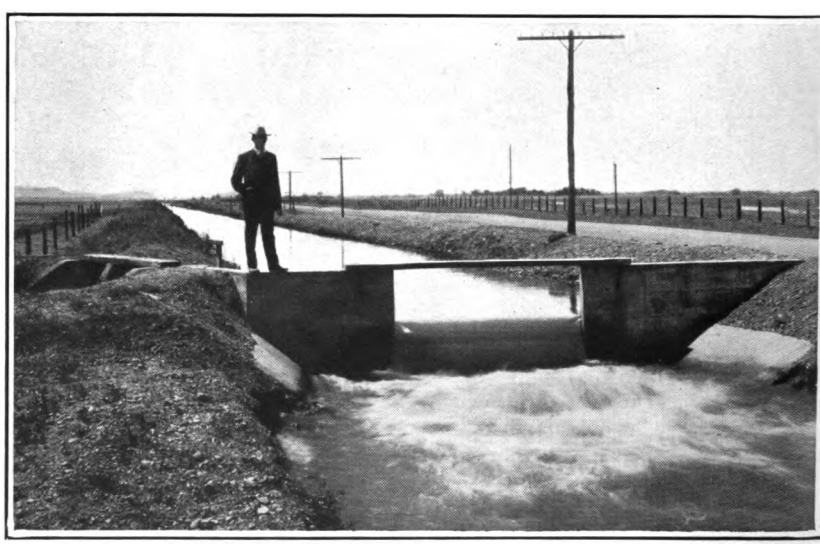

LATERALS, ORLAND PROJECT, CALIFORNIA.

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The land in the Cow Creek bottom east of the boundary canal is of excellent character, but to attempt to water, from the Pit River supply, this rather small area would make the cost excessively high. In that section known as the Stillwater Plains some drainage probably will have to be afforded with the inception of irrigation, but no estimate has been made to provide for this contingency.

Canal system.—The estimates of main canals and laterals total a little more than $31 per acre for 55,000 acres. Regarding this distributing system broadly, it may be said that the construction difficulties are not serious, the project being unusually compact. No long, expensive canals are required to reach detached outlying sections; generally the plan of distribution imposed by the topography is that of a system of laterals extending southerly from the main canal along the various ridges that subdivide the area. The average cost of laterals in each of these subdivisions, exclusive of main canal costs, might be expected to be a little larger than the cost of the laterals on the Orland project, which were built under unusually favorable conditions. The cost of Orland laterals averaged about $10.50 per acre. On the work proposed herein an average of $15 per acre has been allowed. This apparently should be amply sufficient for cost of laterals.

On the Umatilla project, in Oregon, about 20,000 acres are to be supplied by a somewhat complicated system of canals, laterals, and pipe siphons, probably much more costly on the average than the system should be at this point. The average cost of the Umatilla distribution system is, in round numbers, about $30 per acre. This compares well with the aggregate estimate of $31 per acre herein allowed for canals and laterals.

Possible southerly extensions of canal.—To divert water at the Sheep Rocks dam site in sufficient quantity to serve those lands lying south of Hooker Pass, and to construct a canal along the west side of the Sacramento River at sufficient elevation to cross the divide at the above-mentioned place (elevation 548), although possible, does not appear feasible. The crossing of the Sacramento River at Redding and the cost of construction of such a large canal along the broken country to the west of the Sacramento River would be exceedingly high and could be justified only by the increased irrigable acreage served above the level of a possible diversion from the Sacramento River at Anderson, Cal. The additional irrigable acreage that could be thus served is too small to bear this large additional cost.

To construct such a canal along the east side of the Sacramento River presents practically the same difficulties. The canal through a large part of the distance would pass through nonirrigable lands and through a badly broken country, where construction costs would be practically prohibitive.

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Canal on west side of Sacramento River.—To water the lands on the west side of the Sacramento River by means of the Pit River diversion, a siphon crossing 3,000 feet long would be necessitated at a point about 1½ miles above the Redding concrete bridge. The discharge end of this siphon would be at elevation 700. From this point south the canal would traverse a badly broken country, a very small percentage of which is irrigable.

The cost of canal construction would be excessive, and no lands of any great area would be served until the bottom lands of the Cottonwood Creek were reached. The irrigable lands in the Clear Creek bottom are now served by a diversion from that stream, and the Sacramento River bottom lands will be watered by the Anderson-Cottonwood irrigation district's system.

To water those lands on the west side of the Sacramento River which would be served by this canal would cost in the neighborhood of $100 per acre.

The section known locally as Happy Valley comprises some excellent bench lands, a part of which are not irrigated by a diversion from local streams. These lands can be made highly productive with sufficient water, but, since they lie between the 800 and 900 foot contours, it is manifestly impossible to irrigate them from the proposed system. It would seem that an investigation would be justified to determine to what extent the waters of Cottonwood and Clear Creeks could be utilized for this area and the bottom lands along Cottonwood Creek.

Estimates of cost.—In the following estimates of cost no attempt has been made to enter into details owing to lack of definite surveys and by reason of the purposes of this report. The larger items only have been given in the tabulations, all smaller features being covered by lump-sum approximations which have been checked by comparisons of actual expense in similar work elsewhere.

Unit prices used for canal excavation are those that usually prevail in the cost of excavating rock and earth under conditions which permit the use of steam shovels, drag-line excavators, and scraper teams in the various irrigation districts in California. But more particularly have these costs been taken from the actual cost of such work in the Orland project of the United States Reclamation Service in California.

The cost used for earth excavation has been taken upon the basis of a common classification which would include the removal of the hardpan and cement gravel in conjunction with the earth. The canal sections in earth have been designed somewhat shallow in order to avoid excavating any considerable amount of the harder materials which underlie the earth at depths of 3 to 4 feet.

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The cost of concrete lining has been increased over the cost of such work as done on the Orland project, due to the paucity of good gravel beds and lack of roads through the section traversed.

Rock-fill dam:	
Unwatering foundation, including cofferdams, pipes, etc	$206,000
Preparing foundation and excavation	30,000
Excavation spillway and placing rock in dam, 328,000 cubic yards, at $1	328,000
Hand placing 15,000 cubic yards rock, at $1 additional	15,000
Concrete facing and cut-off wall, 8,000 cubic yards, at $8	64,000
Reinforcing steel, 60 tons, at $100	6,000
Concrete in spillway, 500 yards, at $9	4,500
Temporary gates in spillway	12,500
Railroad 2 miles to dam site	30,000
Rights of way, 1,500 acres, at $10	15,000
Total estimated cost of dam	711,000
Tunnel:	
Cost per linear foot—	
Excavation, 4½ cubic yards, per foot, at $6	$27
Timbering, at $7 per foot	7
Concrete lining, 12 inch, 1½ yards, at $12	18
	52
Cost of tunnel—	
13,000 feet, at $52 per linear foot	$676,000
Gates and control works	3,000
Total estimated cost of tunnel	679,000
Main canal:	
Section in rock—station 0+00 to station 264—	
132,000 cubic yards rock, at $1.25	$165,000
13,200 cubic yards concrete, at $10	132,000
Section in earth—station 264 to station 804—	
270,000 cubic yards earth, at $0.35	94,500
Section in earth—station 804 to station 1384—	
174,000 cubic yards earth, at $0.35	60,900
Stream crossings and miscellaneous structures	66,600
Total estimated cost of main canal	519,000

SUMMARY.

Dam	$711,000
Tunnel	679,000
Main canal	519,000
Distribution system	825,000
	2,734,000
Engineering contingencies, etc., 25 per cent	683,000
Total estimated cost of works	3,417,000

On a basis of 55,000 acres irrigable at rate of $62.13 per acre.

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Power development.—The minimum flow of the Pit at the dam site at Sheep Rocks is 2,700; with 600 second-feet diverted into the main canal there will remain a minimum discharge of 2,100 second-feet at the dam. The fall will be 128 feet, so that 29,000 horsepower of theoretic water power, or 23,000 horsepower of electric energy on the switchboard of the power house can be developed. This is figured on the basis of 80 per cent of the theoretic power of the water and with a load factor of 100 per cent.

With the complete control and regulation of the power output that will be possible with the large pondage above the dam, it will be practicable to take care of any variable load that commercial demands may impose. If the power output be utilized on the basis of a 50 per cent load factor, the power that can be sold may be in excess of a 46,000 horsepower maximum on the switchboard.

It is not practicable to estimate the value of the power privilege afforded by the dam under conditions such as this. Probably under the market conditions of to-day there would be no demand for the power in view of the large amount of excess power already developed and unmarketed in northern California. It is evident, however, that this power privilege, which will be a mere incident or by-product to the irrigation works, will afford a remarkably favorable opportunity for cheap development of power and in process of time will become marketable. Whenever the demand for power justifies the development of a plant at the dam site, a value to the privilege will be established that might readily reach into the hundreds of thousands. Such value, whatever it might be, would then become an asset of the irrigation system that would go to reduce the cost of the works to the irrigators. In these estimates no credit is made on account of the power privilege by reason of present uncertainties of valuation.

SOILS.

Soil surveys.—A report of the soil survey of the Redding area, published in the Field Operations of the Bureau of Soils in 1907, was used in the study of the soil made for this report. The Bureau of Soils' survey covers the larger part of irrigable area. The present investigations were extended from the Bureau of Soils' map in each direction to include the irrigable area of the project. The following quotations from the above-mentioned report describe the soils:

"Three types of soil occur in the uplands—the Redding gravelly loam, the Redding loam, and rough stony land. These soil types merge gradually into one another and into other adjacent types. The separating of these soils was therefore more or less arbitrary. The soil types differ widely in adaptation to crops and in agricultural value, depending upon adaptability to and the facilities for irrigation and the occurrence, character, and position of the hardpan.

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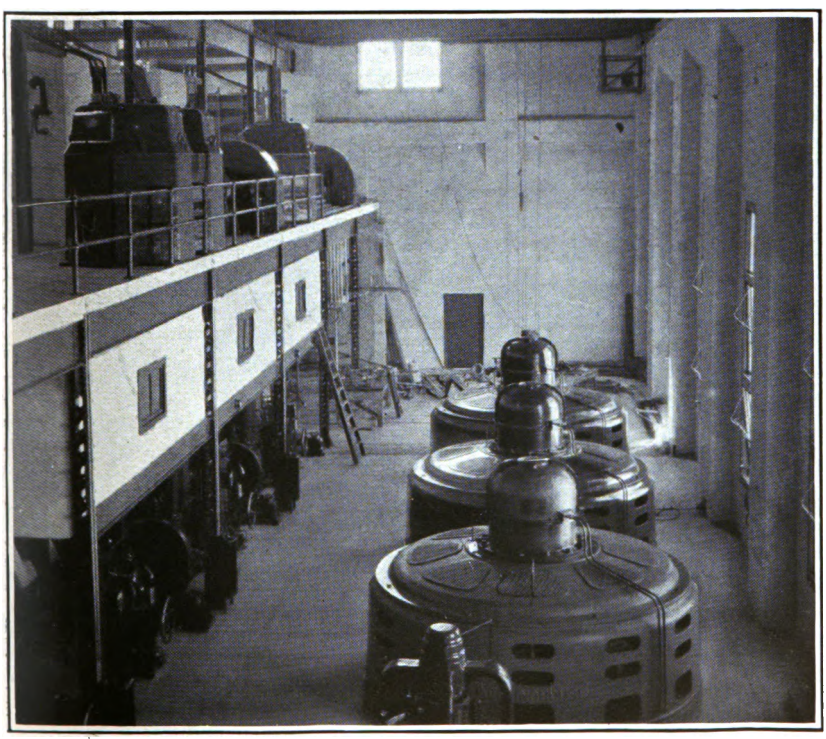
SPILLWAY AND GATES OF A LARGE ROCKFILL DAM, MINIDOKA, IDAHO.



INTERIOR OF A 12,000-HORSEPOWER HYDROELECTRIC PLANT, MINIDOKA, IDAHO.

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VIEW OF WOODED UPLANDS ON REDDING GRAVELLY LOAM SOIL.

VEGETATION ON REDDING GRAVELLY LOAM.

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"The soils of the valley slopes consist of three types—two of the Anderson series and one local type, the Bellavista sandy loam. They usually are found adjacent to the soils of the uplands, occupying the higher valley slopes, flat-bottomed gulches, and the valleys of intermittent streams. They are usually gray to reddish in color, well drained, sometimes slightly gullied, usually wooded or covered with brush, gravelly, and generally free from hardpan.

"The soils of this group are formed by direct wash from the adjacent upland slopes and by deposition in the narrow stream valleys of material carried down by flood waters, the material having been transported for only short distances. While often of a pervious and leachy character, they are usually fairly well adapted to agriculture.

"Five types of the stream-bottom soils were encountered, four being soils of Sacramento series, the remaining one a nonagricultural type, Riverwash. These soils occupy the lower bottoms of the Sacramento and minor stream valleys, varying in texture from coarse sands and gravels to rather compact silt loams, and in color from light gray to dark brown. They are generally well drained, but subject to overflow, which in case of the types occurs annually. They may be barren of vegetation in spots, but are generally wooded, and often gravelly but free from hardpan.

"The soils of this group consist of recent stream deposits, occurring along present or recent stream flood plains, made up of a variety of mineral constituents which have been transported considerable distances. The soil bodies are often small in size, having an elongated outline extending in the direction of stream channels, and are sometimes subject to considerable modification by the erosive effects of floods or the further deposition of material by flood waters. In agricultural importance they range from relatively worthless to the most important and valuable soils of the area."

Of the area studied, 7,000 acres, or 10 per cent, are regarded as bottomland and 60,000 acres, or 90 per cent, as upland. Since the upland is more abundant and as it is the area whose soil is questionable in agricultural value, more extensive description of these upland types will be given.

REDDING GRAVELLY LOAM.

"The Redding gravelly loam varies greatly in texture, structure, depth, and in agricultural importance. Typically it consists of a heavy sticky loam of fine silty texture, red to dark red in color, extending to a depth of 6 to 15 inches and carrying small to relatively large quantities of subangular, rounded, or flattened cobbles, pebbles, or fine gravelly material. In limited areas the accumulation of cobbles and gravel in the surface is sometimes excessive, due to the removal of the fine earth by wind action or by erosion.

"Although the soil is of a heavy tenacious character, the finer clay material is generally flocculated; which condition, together with the large quantity of gravel, renders the soil friable, readily cultivated, and capable of maintaining an excellent tilth.

"A compact and usually adobelike heavy loam of deep-red color, carrying a moderate quantity of gravel, usually underlies the soil at

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"The subsoil is underlain by a clay or sandy clay hardpan, red or yellowish gray in color, mottled with reddish yellow, or by a heavy dark-red or yellow clay containing hardpan layers. The hardpan may or may not contain cobbles or gravel, and is similar to that of the Redding gravelly loam, except that it is generally more dense and impervious and usually nearer the surface, sometimes outcropping where the surface soil has been eroded.

"The Redding loam occurs in a few moderately extensive bodies in the southeastern part of the area, and merges almost imperceptibly into the adjacent bodies of the Redding gravelly loam or is separated from the lower lying soils of the valley slopes and the stream bottoms by bluff or terrace lines. The areas of this type occupy slightly sloping, treeless sections of the upland plain. The surface is frequently marked by the presence of hog wallows and small drainage depressions occupied by pools of water or by areas of checked and puddled soils.

"Redding loam is sedimentary soil derived from ancient alluvium, once filling the greater part of the Sacramento Valley to a great depth.

"Owing to the occurrence of hardpan, the shallow nature of the soil, and to its position in unirrigated sections of the area, this soil type is of secondary agricultural importance, being usually devoted to grazing or to dry farming to wheat. In a few favorably located districts, where the deeper soil is found, small fruits and tree fruits could be profitably grown under irrigation, while table and wine grapes could probably be grown in limited areas by thorough cultivation.

"Numerous attempts at fruit culture upon the shallow phase of the Redding loam without irrigation have resulted in failure, led to discouragement, and given an erroneous impression of the Redding area for fruit production."

ROUGH STONY LAND.

"Rough stony land of the Redding area in the character of the soil material is similar to the bodies of the Redding gravelly loam and the Redding loam into which it merges.

"It consist of a few inches to 18 inches or more of light-red, gray, or yellowish-red to deep-red loam or clay loam carrying a relative large quantity of water-worn cobbles, shallow bowlders, and gravel. It is underlain by yellow or red to gray clays, indurated clay hardpan frequently carrying an excessive quantity of gravel and cobbles or by beds of volcanic ash and breccias.

"It occurs in the northern and northeastern parts of the area as irregular or narrow elongated bodies bordering stream valleys. It is usually separated from the soils of the valley slopes and the stream bottoms by high bluffs and rough stony slopes. It occupies the higher, hilly, and more deeply dissected sections of the uplands, and is generally wooded or covered with more or less brush, although barren in some places.

"The rough stony land is derived from the ancient alluvial deposits of the old valley and from the underlying volcanic muds and breccias."

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ABANDONED FARM ON EDGE OF STILLWATER PLAIN.

LEVEL LAND, GRASS COVERED, STILLWATER PLAIN.

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The bottom-land types, making up about 10 per cent of the area, are briefly described by the Bureau of Soils as follows:

ANDERSON GRAVELLY LOAM.

"The Anderson gravelly loam typically consists of a moderately heavy, sticky loam of light-red color, extending to a depth of 8 to 12 inches and carrying a moderate quantity of small, flattened, or rounded pebbles, or cobbles, and considerable fine subangular or rounded gravel. It is somewhat compact in structure, but friable when cultivated. It is sometimes, however, very gravelly and of lighter color, and in such cases usually grades into the Sacramento gravelly sandy loam. In other locations it is of a fine, silty, compact character, of deeper red color, and grades into the adjacent more elevated soils of the dissected plains and lower foothills.

"The Anderson gravelly loam is derived mainly from the adjacent and more elevated formations of the early stream gravels and sediments, giving rise to the soils of the uplands. It is of rather recent alluvial origin, the material forming it having been transported only short distances and distributed by the flood waters of intermittent streams. Under irrigation it is well adapted to peaches and grapes, and if well cultivated in favorable locations produces fair yields of these crops without irrigation. Alfalfa is also grown to a very limited extent on some of the irrigated parts of the type. Much of this soil is, however, utilized only for grazing.

"With thorough cultivation, supplemented when practicable by irrigation from private reservoirs or by the pumping of ground water, considerable areas of the less gravelly and porous bodies of this soil type, now used only for grazing, can eventually be rendered productive and brought under cultivation."

THE ANDERSON FINE SANDY LOAM.

"The Anderson fine sandy loam consists typically of a fine sandy loam of light-red to grayish-red color, generally carrying a moderate amount of rather small subangular or waterworn gravel, and extending to a depth of 3 to 6 or more feet. It is somewhat porous and friable and easily maintained in a good condition of tilth. When less than 6 feet in depth it is generally underlain by river sands and gravels, although occasionally by hardpans, clays, or volcanic tuff.

"This soil type is not extensive and occurs mainly as narrow, elongated bodies, occupying the bottoms and slopes of the narrow valleys of Churn and Stillwater Creeks, often grading quite imperceptibly into the adjacent soil types.

"The Anderson fine sandy loam where not subject to overflow is well drained, moderately retentive of moisture under cultivation, and well adapted to the production, with or without irrigation, of grapes, peaches, pears, small fruits, and alfalfa, although irrigation is advised where practicable. It is, when cleared, usually devoted to dry farming to grain, or to peaches, prunes, pears, and grapes. The yield is generally somewhat less upon the soils of the Sacramento series, but the fruits produced are of excellent quality."

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Hardpan.—In addition to extending the soil examination as carried on by the Department of Agriculture to cover the irrigable area, especial examination was made of the prevalence of hardpan or cemented gravel. This investigation was made by examining wells, digging holes, making borings, and observing banks and stream cuts to determine the percentage of land regarded as irrigable. The lands were classified into four grades as follows:

(*a*) Land with hardpan and cemented gravel less than 2 feet from the surface, the hardpan being of such a nature that it can be shattered by blasting.
(*b*) Hardpan and cemented gravel 2 to 4 feet from the surface.
(*c*) Hardpan more than 4 feet from the surface.
(*d*) Nonirrigable land—that is to say, land in which the hardpan is closer than 2 feet to the surface and too thick to permit economical blasting, where the percentage of gravel was so great as to render cultivation or irrigation impracticable.

As a result of this examination the areas of each of these grades of land were found to be as shown in the table below:

	Area.	Of this there is irrigable.
Grade of land:	*Acres.*	*Acres.*
a	13,500	13,500
b	23,500	23,500
c	24,500	24,000
d	8,500	.....
Total	70,000	61,000
Deduct for safety 10 per cent	.....	6,000
Net irrigable	.....	55,000

The question of hardpan and cemented gravel is one of the most important points to be considered in determining the agricultural value of the lands of this project. If this large area of land had been unquestionably deep and fertile no doubt an effort to bring it under irrigation would have been made years ago. The fact that more or less hardpan is present and that in places the surface soil contains gravel seems to have caused some doubt as to the value of the land. The great depth of the majority of soils of the west and of California in particular has created an impression in the minds of most people familiar with irrigation that none but deep lands are capable of producing good crops or of maintaining the growth of orchard trees for any considerable number of years. It is easy to overlook the thousands of acres of orchard and farm land in the Appalachian and Atlantic Coast States where farming and fruit raising have been carried on for over 100 years with success and where the soil is seldom over 2 to 3 feet deep. It is easy to overlook the fact that

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under Eastern conditions many crops grow and thrive and seldom send their roots to a greater depth than 24 inches. The difference in depth of root system is not due to any change in the rooting habit of the plants when brought West, but is due to the deeper soils found under semiarid and arid conditions. These same plants can thrive on a thin soil in California just as well as in New York or North Carolina. Deep soils are desirable, but not necessary.

Irrigation when properly conducted introduces no new feature of farming which makes deep soil necessary. Where water is supplied artificially the amount must be controlled so as not to flood the subsoil with an excess and drown out the roots of plants. Good drainage is, of course, essential in any method of agriculture, whether irrigated or not.

The hardpan in the Redding neighborhood varies greatly in depth and thickness. It may be within a few inches of the surface of the ground or several feet down. It may be an inch or several feet thick. It may be a gravel or a clay, or sand cemented with iron oxide. Lime may occur as cementing material, but it is in small amount. The cementing material is generally iron.

The hardpan is generally underlain by a layer of soil or subsoil; sometimes, however, it is very thick and underlain by more hardpan.

For the purposes of this report we have considered hardpan more than 3 feet as too thick for successful blasting, and have considered such land as nonirrigable and have excluded it from the project. No areas of large size were found within the district outlined on the map, but outside this area, particularly toward the east, extensive areas of deep and impenetrable hardpan were found. The elevated plains, such as the Swede Creek plains, and similar plains to the south, are underlain by deep and impenetrable hardpan, and have been regarded as nonirrigable.

In the classification of the land as outlined above, grade "a" will be useful for nearly all classes of fruit crops. Grade "b" will be useful for fruit and forage crops. Alfalfa will thrive on it, but may require replanting every four or five years. Grade "c" will be available for all classes of crops. Grade "d" is regarded as nonirrigable, but there may be small areas of this land deep enough for successful crop production.

The maps showing the approximate segregation of these areas are not published with this report, but are filed with the survey notes.

Similar soils in other localities.—Theoretical considerations alone should not govern in the determination of so important a point as the effect of hardpan and cemented gravel upon the agricultural value of these lands. Fortunately large areas of such lands are already under successful cultivation in near-by localities, and a brief statement of results accomplished will do much to settle this point.

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Soils very similar in physical and chemical composition to those found around Redding are found in many parts of California under successful cultivation, the most important localities being in Happy Valley, 5 miles west of Anderson; the Los Molinos irrigation project, 15 miles south of Red Bluff; around Corning in Tehama County and around Oroville and Palermo in Butte County.

Happy Valley district adjoins the areas surveyed. The soils here are almost identical physically and chemically with the soils of a large part of the country east of Redding. Orchards from 10 to 20 years old are found in Happy Valley region, producing excellent crops of peaches, olives, prunes, plums, and apricots, and the trees show no signs of either lack of soil depth or plant food. An examination was made in a number of these orchards, revealing in many places cemented gravel at depths of 2 to 3 feet. Where irrigation and cultivation are properly practiced the trees produce as well as where the soil is much deeper. New orchards in this region are invariably blasted and the subsoil broken up. This is found to encourage the growth of young trees. Some of the older orchards were planted without blasting. It is well demonstrated that where the land has been properly blasted, though hardpan is only 2 feet from the surface, trees will produce good crops.

A portion of the Los Molinos irrigation project extends out upon the edge of cemented gravel and hardpan land—though the larger part of the district has deep soil. A portion of this project where the soil is thin has been under cultivation for from five to eight years, and it has been found a rule that wherever care was exercised in planting the land a depth of 2 to 4 feet of soil is sufficient for fruit trees.

Alfalfa produces good crops with the soil from 2 to 4 feet deep, though we have no evidence as to how long the stand can be maintained with this depth of soil. Blasting the subsoil for planting the orchards is common in this region. It is believed by experienced fruit growers in this neighborhood that 2 feet of good soil will maintain orchards, particularly if the subsoil below that depth is blasted.

Around Corning there are areas of fruit lands planted upon shallow soil. From 2 feet to 6 feet of soil only is encountered in some orchards, and in many of the older plantings where no blasting was done the trees are producing good crops of fruit where cultivated and irrigated. Blasting is now the practice around Corning on lands whether hardpan is present or not when fruit trees are planted, and it is the opinion of experienced growers of fruit that 4 feet of soil is sufficient for any fruit crop.

The region around Oroville is the largest fruit district in northern California in which hardpan and cemented gravel are encountered.

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A 15-YEAR-OLD OLIVE ORCHARD NEAR PALERMO, CAL.

AN ORANGE ORCHARD IN PROFITABLE BEARING, NEAR PALERMO, CAL.

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Hundreds of acres of orchards are found in the Oroville neighborhood where soil does not exceed 4 feet in depth, and it has been found that cultivation and care have more to do with the success of the orchard than has the depth of the soil. Ten to twenty year old bearing orchards are seen on soils not exceeding 2 to 4 feet, and no signs of deterioration in these orchards can be found where any reasonable care has been given them. It is the practice in this region to blast the subsoil wherever fruit trees are planted, regardless of whether hardpan is present, and if it is blasted the practice will insure the permanent success of the orchard. Many old orchards were not blasted, and yet good crops are produced on land with 2 to 3 feet of soil above the hardpan.

There are other fruit districts in California where hardpan is encountered and where the practice of blasting land has become prevalent.

In brief, it may be said that the theory that crops of fruit could be grown only on very deep land does not apply to California conditions, but that any soil which is fertile and 2 feet or more in depth can be made productive of a fruit crop if the trees are cared for and irrigation water supplied.

The examination of the region around Redding leads to the belief that practically all of the district which it is possible to water can be made good fruit land. A very large proportion of this land is useful for the production of alfalfa or any forage crops grown in California.

Chemical composition of the soils.—The chemical composition of a soil to a great degree determines its ability to produce crops. Four typical samples of soil and subsoil were collected and subjected to analysis. The amount of plant-food material dissolved by strong hydrochloric acid was determined. The results appear in the table which follows:

	Sec. 34, T. 31 N., R. 4 W.		Sec. 9, T. 31 N., R. 4 W.		Sec. 2, T. 32 N., R. 4 W.		Sec. 26, T. 33 N., R. 4 W.	
	0–12 inches.	12–24 inches.	0–12 inches.	12–24 inches.	0–12 inches.	12–24 inches.	0–12 inches.	12–24 inches.
Lime CaO	Tr.	0.10	0.16	0.11	1.09	2.32	0.40	0.36
Magnesia MgO	0.16	.31	.18	.33	1.70	1.85	.34	.36
Potash K_2O	.24	.43	.41	.44	.46	.50	.33	.40
Phosphoric acid P_2O_5	.08	.10	.08	.10	.12	.12	.10	.12
Carbonates CO_2					Tr.	Tr.		
Nitrogen N	.060	.050	.058	.040	.075	.062	.057	nil.

No. 1. Redding loam, Stillwater Plains. Barren surface.
No. 2. Redding gravelly loam. Upland heavily wooded; very fertile where cultivated.
No. 3. Sacramento loam. Bottom land. Houston place, good yield crops, now in grain.
No. 4. Redding gravelly loam, upland in cultivation, Lilventhals place—orchard and vines doing well. In cultivation 16 years.

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These chemical analyses show the upland soils to be rather deficient in lime, well supplied with potash, with more phosphoric acid than is often found in fertile California soils, and with fair amounts of nitrogen. So far as the analyses show, the soils will produce good crops for many years.

The bottom soils differ from the upland only in carrying more lime and slightly larger amounts of the other essential plant-food elements.

Lime alone occurs in the immediate neighborhood of this project in large quantities, and can be supplied at very low cost if its use ever becomes necessary.

Alkali or other harmful salts are not present, and should never cause trouble in this region.

AGRICULTURAL POSSIBILITIES OF THE LAND.

Possible crops.—As stated elsewhere, climatic conditions are such that all classes of crops (except citrus fruits) now grown on a commercial scale in California may be grown under the Lower Pit River project. This statement is not based upon opinions only, for most of these crops are actually grown in some parts of the district or in the immediate neighborhood.

Within the last 30 years many small farms have been cleared and planted to a variety of crops. Bottom land and upland have thus been tried, both with and without irrigation. Many of the unirrigated farms thus started have been abandoned, but the irrigated places are still cared for and are returning profits.

The examination of these old farms gives very valuable suggestions as to the kind of crops which are best adapted to the region. Olive, fig, and almond trees seem to thrive best and to live without care or attention much longer than any other trees. In many old orchards these are the only varieties of trees remaining. Peaches, prunes, plums, apricots, apples, and grapes generally die after a few years of neglect. Where cultivation has been continued all of the trees do much better; most of them live, though the olives, figs, and almonds seem to thrive best. On bottom lands, or where irrigation water is available, all classes of fruit trees do well.

The fruit business depends more for its success on the marketing arrangements than on any other one factor. Shasta County conditions are no exception to this rule, and it may be said that the future of the fruit business will depend on the marketing organizations perfected.

Alfalfa is now grown only in a few places, but with success. Without irrigation the yields are fair; three crops can generally be cut. With irrigation five to seven crops are possible, yielding 5 to

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OLIVE ORCHARD NEAR REDDING, CAL.

GENERAL VIEW SHOWING WOODED UPLANDS.

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10 tons per acre. Corn, sorghum, Kaffir corn, and other nonsaccharine sorghums can all be produced in large quantities.

Feeding of cattle, hogs, and sheep should be greatly increased when irrigation becomes general. The large area of range land in the neighboring mountains and foothills will serve to produce young animals cheaply, and the irrigated regions of the valley will become the feeding yards. Irrigation will thus increase the value of the range lands.

Clearing and preparing the land.—A very large proportion of the irrigable land of the project is covered with native timber and brush. The cost of clearing land and preparing it for irrigated crops will vary greatly. Clearing alone may cost up to $40 per acre. In the Happy Valley neighborhood large areas have recently been cleared both by contract and by day work. The work was done by steam stump pullers and by use of dynamite. The cost has been as high as $40 to $50 per acre. The vegetation at Happy Valley is as heavy as anywhere on the project, and the price for clearing is probably maximum. Other contracts for clearing have been investigated, and it is believed the price of $40 per acre is a maximum and that on only a small part of the area will it cost so much. Much of the land is in brush and light growth of trees and can be cleared for prices around $10 per acre. The value of the wood cleared may somewhat reduce the price of clearing, but the market for wood is so small this has not been considered. Conditions of native vegetation are illustrated on plate 10.

During the field examination of the land estimates by sections were made of the cost of clearing the land. The deduced average price was about $25. Fortunately, the poorer grades of land have the least timber and brush and will be less costly to prepare for irrigation.

The cost of leveling and checking land will vary over wide limits, but as much of the rougher land will be put in fruit and furrow irrigated, the cost will be less than if alfalfa or other flooded crops were planted. The average cost of preparing land, in addition to clearing it of trees and brush, will be somewhere around $20 per acre.

Statement by G. A. Lamiman.—The following statement by Mr. George A. Lamiman, county horticultural commissioner of Shasta County, expresses the opinion of a man of long practical experience in fruit growing:

"The possibilities of the fruit-growing industry in Shasta County are large, and the character of the soils of the different sections of the county is conducive to great diversification.

"Much of the table-lands and foothills where irrigation may be had is of such character as to produce the finest colored fruit with a high sugar content and splendid carrying qualities, making a desirable market product which always attracts attention wherever seen.

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"The olive is now being planted on the red soil of the table-lands where it seems to have found its natural home, and ripens here two weeks earlier than in any other part of the State. This in itself is well worth the consideration of the prospective planter.

"The grape, too, finds a soil to its liking and the high color of the fruit makes it very attractive. The analysis of this fruit shows a sugar content of 28.8 per cent.

"The above statements refer to the places where irrigation is now practiced and where but a small acreage, in comparison to the amount of land which might be under irrigation if water were available, is now producing fine products.

"There are splendid fruit lands on the east side of the Sacramento River which would make a great producing section if water were available, where now little is grown.

"Much of this land would no doubt produce good crops of alfalfa, where under present conditions it can not be grown because of the lack of adequate irrigation.

"If water were available for irrigation, this land would produce the following fruits: Peaches, plums, apricots, cherries, apples, pears, all varieties of berries and other fruits of like nature."

Statement by Thos. Francis Hunt.—The fruit industry seemed such an important matter in considering the agricultural possibilities of the Lower Pit River project that the director of the experiment station of the University of California was requested to furnish a chapter for this report. Mr. Thos. Francis Hunt of the experiment station spent a week in a special investigation of the matter, and his report follows:

"REPORT OF AGRICULTURAL CONDITIONS UNDER THE PROPOSED PIT RIVER PROJECT IN SHASTA COUNTY, CALIFORNIA.

"*General.*—The area to be covered by this project begins about 6 miles north of the town of Redding on about an 800-foot contour, following a uniform grade along the hills on the east just beyond Cow Creek, then south to the Sacramento River opposite the town of Anderson. On the west, the line comes south to the Sacramento River a little north of the town of Redding, then follows the Sacramento River on the east side until it meets the east line again opposite Anderson. There is also a narrow strip on the west side of the river beginning at the town of Redding parallel to the Southern Pacific Railroad down to and including a narrow strip on Cottonwood Creek. According to the preliminary survey, this will include approximately 60,000 acres on the east side of the river and about 40,000 acres on the west side.

"In this area of 100,000 acres, there is quite a variety of soils, rainfall and temperatures represented, all of which have a very important bearing on crop production. There are three distinct types of conditions represented, viz, first, there is what is generally termed mesa or bench lands; second, the plains lands; and third, the river and creek bottoms.

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OLIVE GROVE IN HAPPY VALLEY DISTRICT.

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"*The mesa or bench lands.*—On both the east and west sides of the project there is a large area which is at a higher elevation. This area is usually the top of what is generally termed "ridges." These ridges vary in width from a mile to 4 or 5 miles wide and 10 to 12 miles in length. The soils on these ridges are mainly red clay loam, gray clay loam, and red clay. They are usually from 3 to 6 feet in depth, underlaid with small bowlders and gravel, well drained, practically no alkali or hardpan apparent. These ridges are usually covered with white and black oak, a few white pine, manzanita, poison oak, and small shrubs. The soils on these ridges are very fertile, and with ordinary cultural conditions grow, even under dry-farming methods, fine quality and fair quantity of all the fruits and crops that can be grown in the Sacramento Valley, with the possible exception of citrus fruits. The red loam soils, on which oaks have been found growing, on complete chemical analysis by the Hilgard method, made at the California experiment station, show a notable lack of lime and phosphoric acid. The heavier red soils, on which chaparral is the natural vegetation, are much better supplied with lime and phosphoric acid, yet they are slightly deficient in those materials by our ordinary standards for judging such analyses. The humus content is generally higher in all but the plains soils than in most of the typically arid California soils. This supplies a satisfactory nitrogen content, and direct analysis by the methods above referred to shows an ample supply of potash. Where water has been developed the success of crop production is assured. From the data that are available and external evidences the danger of frost in this area is less than in other parts of the project.

"*The plains lands.*—The area lying just below the bench lands and slightly higher than the bottom land on both sides of the valley is what is generally termed the "plains land." These plains are comparatively level, a little rolling or undulating. The soils are light gray, brown to red in color. They are usually very gravelly and excessively drained and very low in humus. Under the dry-farming conditions as they exist these soils are very low in crop production. Large tracts of this type are lying idle or used for pasture for a short period each year. This type is the least desirable of any in the project, but with water and under judicious management can be made to produce crops to which they are adapted.

"*Bottom lands.*—There is considerable land lying along the Sacramento River, Churn, Stillwater, and Cow Creeks. The soil in these bottoms is mostly loams, deep, well drained, and comparatively free from alkali. This soil is very fertile and will yield large quantities of the crop to which it is adapted. Because the land along the river and creek bottoms is usually level, fertile, and retentive of moisture, there are farms which have been in operation many years. Some of these are growing fruit, but most of them are utilized for general farming. Grain growing, alfalfa, stock raising, and dairying are the most important lines of agriculture, and are generally very successful. These bottom lands are well adapted to growing prunes, pears, peaches, walnuts, berries, and annual crops. Crops that will not stand frost are not to be recommended for this location, as occasional spring frosts sometimes occur and there is danger of injury to tender varieties. Average date of killing frosts at Red-

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ding, February 20 and November 27; latest and earliest killing frosts, May 1 and October 17.[1]

"*Present status of agriculture in this area.*—Shasta County has been and is now a county where mining has been the most important industry, and its agriculture has not been developed to its highest possibilities. The county is rather sparsely settled, and the character of the farming at present is hardly up to the average of the State. At present stock raising and grain farming are most important. The fruit industry is quite well developed in certain small areas, as around Anderson, Happy Valley, and Cottonwood. The most important fruits are prunes, pears, and peaches.

"*Possibilities.*—The area under this proposed project offers great possibilities for agricultural development. The bench lands, when supplied with water, should make a very fine fruit section. At present there are few commercial orchards in this part of the project. but there are enough family orchards scattered around to furnish evidence as to what can be done in a commercial way.

Mean monthly and annual rainfall and temperature at stations in the Sierra foothills.

[Tables from Bulletin No. 253, Agricultural Experiment Station, Berkeley, Cal.]

RAINFALL.

Station	Elevation.	Years recorded.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Annual.
	Feet.	*No.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*
Porterville	464	25	1.85	1.62	1.85	0.79	0.71	0.11	0.01	0.01	0.29	0.52	0.76	1.49	10.02
Jamestown	1,471	11	8.90	5.01	8.21	2.22	1.47	.24	.00	.00	.64	1.18	1.92	4.14	33.93
Mokelumne Hill	1,550	21	5.40	4.93	6.24	2.79	1.57	.41	.00	.02	.59	1.64	3.72	5.22	32.55
Oroville	250	30	5.48	4.33	4.20	1.98	1.46	.33	.02	.02	.71	1.62	3.47	4.78	28.40
Placerville	1,875	37	8.23	6.31	7.86	4.25	2.19	.66	.02	.03	.72	2.29	4.84	7.22	44.62
Auburn	1,360	43	6.51	5.58	5.72	3.02	1.52	.44	.01	.02	.53	1.94	3.92	5.92	35.13
Nevada City	2,580	43	10.60	8.19	8.193	4.50	2.39	.67	.02	.05	.77	2.62	6.19	10.39	55.32
Redding	552	39	7.77	5.57	5.38	2.96	2.24	.73	.09	.07	.78	2.42	4.17	6.54	38.72

TEMPERATURES.

	Feet.	*No.*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*
Porterville	464	25	48.0	51.8	56.2	66.9	70.3	78 8	84.8	82.6	75.1	64.9	54.9	47.8	64.8
Jamestown	1,471	11	45.0	47.5	50.8	55.7	60.0	68.2	75.3	73.9	68.2	59.9	50.9	43.7	58.3
Mokelumne Hill	1,550	21	43.6	46.8	48.6	54.7	58 8	68.1	76.8	74.2	67.8	60.3	51.8	44.2	58.0
Oroville	250	30	46.8	50.6	54.3	59.5	66.1	74.5	80.2	78.6	73.0	65.4	55.9	47.8	62.8
Placerville	1,875	25	41.6	44.3	47.4	52.2	58.0	66.4	72.6	69.9	63.5	56.3	48.1	42.4	55.2
Auburn	1,360	43	45.6	48.1	51.7	56.5	62.7	70.8	76.8	75.9	71.0	64.6	55.0	47.0	60.5
Nevada City	2,580	22	41.5	43.1	44.8	50.5	55.6	62.7	68.8	68.1	62.2	55.7	47.8	42.4	53.6
Redding	552	39	45.2	49.3	53.8	60.2	67.2	75.6	82.3	81.0	74.0	64.5	54.1	47.0	62.9

"Above is a table showing the rainfall and temperatures of this section and other fruit sections. A little study of these tables will show that conditions are very similar to some of the proved agricultural sections. These records represent conditions at the town of Redding. On the bench lands, frost conditions are undoubtedly better than this record shows, as is indorsed by comparison of trees growing in the two sections. The writer observed trees growing in

[1] Taken from United States Weather Bureau Reports.

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this section doing remarkably well with very ordinary care. Prunes, peaches, olives, apples, pears, cherries, almonds, and berries do well here. There is enough evidence present to show that the growing of these crops is beyond the experimental stage. Considerable development is being done in Happy Valley, where the Elman Olive Co. has extensive plantings of young and mature trees. This section is typical of a large area which is capable of a very high state of development.

"CROPS WORTHY OF SPECIAL MENTION.

"*Olives.*—The olive is attracting a great deal of attention at the present time and considerable planting has been done in this section. There are enough old trees in bearing in various places to show what can be done, and there are a good many thousand acres of land where the conditions are suitable for successful olive culture. With irrigation water, the bench lands should make fine olive orchards.

"*Almonds.*—The writer was particularly impressed with conditions for almond culture. The soil on the bench lands seems to be ideal for growing almond trees. A great many old almond trees were found which had received no care for a great many years, yet they were in good healthy vigorous condition and have good crops. One attempting to grow this crop will have to give careful attention to the selection of the site for the orchard, with regard to thermal belts, exposure, etc. Also more detailed information will have to be obtained as to varieties suited to the conditions. From the evidence and data that could be obtained, there seem to be great possibilities for the growing of this crop.

"*Walnuts.*—Walnut growing, along the river and creek lands, offers good opportunity. In attempting to grow this crop it is extremely important to select the deep loam soils. There are a great many acres of this type that can be utilized for this crop. Some very fine specimen trees are to be seen in the old Aloha orchard. These trees are probably 15 to 20 years old and bear fairly well. They are seedling trees and are not particularly good types, but they have made good growth and show what it is possible to do with grafted trees of the best-known varieties.

"*Fruits.*—No more comment needs to be made about growing of apples, pears, plums, cherries, apricots, and grapes, because these grow so well and are grown to such an extent that it is no longer a matter of conjecture as to the possibilities of these crops.

"In regard to citrus fruits, the red soils are ideal for growing the trees, but from the climatic conditions, there does not seem to be evidence enough to warrant rendering an opinion as to citrus possibilities. Some winters snow falls and stays on the trees a few days, and it is possible that this might break them down. It would not be surprising if small thermal belts were found where it is possible to grow citrus fruits, but this will have to be proven by growing citrus trees in experimental plantings.

"*The effects of the use of irrigation water on this land.*—Most of the agriculture in Shasta County is carried on without the aid of irrigation water. There are a few small projects, one at Happy Valley covering about 6,000 acres, and a few private irrigation plants are in operation. Wherever water is obtained and used on the land the

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crops are very materially increased. In some instances the yield has been doubled. In regard to this project, I think there is no question as to the advisability of procuring water to be applied to this land. If water can be obtained at a reasonable rate, thousands of acres of very productive agricultural land can be made to yield good crops. In doing this, the matter of drainage should be taken into consideration along with the irrigation schemes, and the cost of the drainage system should be figured with the irrigation system. Because of the general topography of this project and the number of sloughs and streams running through it, I think the matter of drainage would not be as important a consideration as is true with a great many of the irrigation projects in the State."

Nearby irrigation projects.—One of the best methods of determining whether or not an irrigation project is feasible is to see the results of irrigation in near-by districts where climatic conditions, soils, crops, and markets are similar to those in the district proposed. There are several small successful irrigation developments in the neighborhood of the Lower Pit River project, and it is believed that these will show whether or not success can be expected in the development of this scheme.

West of Anderson, about 15 miles southwest of Redding, an irrigation project known as the Happy Valley project has been in successful operation for a number of years. Here a small ditch was originally built for hydraulic mining; later it was extended and enlarged for use as an irrigation ditch. The ditch diverts water from the north fork of Cottonwood Creek and from a branch of Clear Creek. It supplies at the present time approximately 4,000 acres of land. More land is being developed each year, and it is expected that by the time this project reaches its full development from 6,000 to 10,000 acres will be irrigated. Here the climatic conditions are practically identical with those in the Lower Pit River project.

In Happy Valley, olives, peaches, prunes, plums, and other deciduous fruits are profitably grown. The farmers practice the growing of strawberries, blackberries, and loganberries and truck crops between the trees, thus increasing their yields and profits.

Alfalfa is raised as yet in a small way only and entirely for home consumption.

The district is noted for early fruits and for the excellent quality of olives produced. Early fruit is shipped largely to the markets of Oregon and Washington, and the later fruits are dried or shipped to eastern markets. Within the last two or three years extensive plantings of olives have taken place in this district, and there is promise that this will become an extensive olive-producing region.

On the east side of the Sacramento River, below Red Bluff, lies the Los Molinos irrigation project, covering about 12,000 acres of land. This project received water from Antelope Creek and Los

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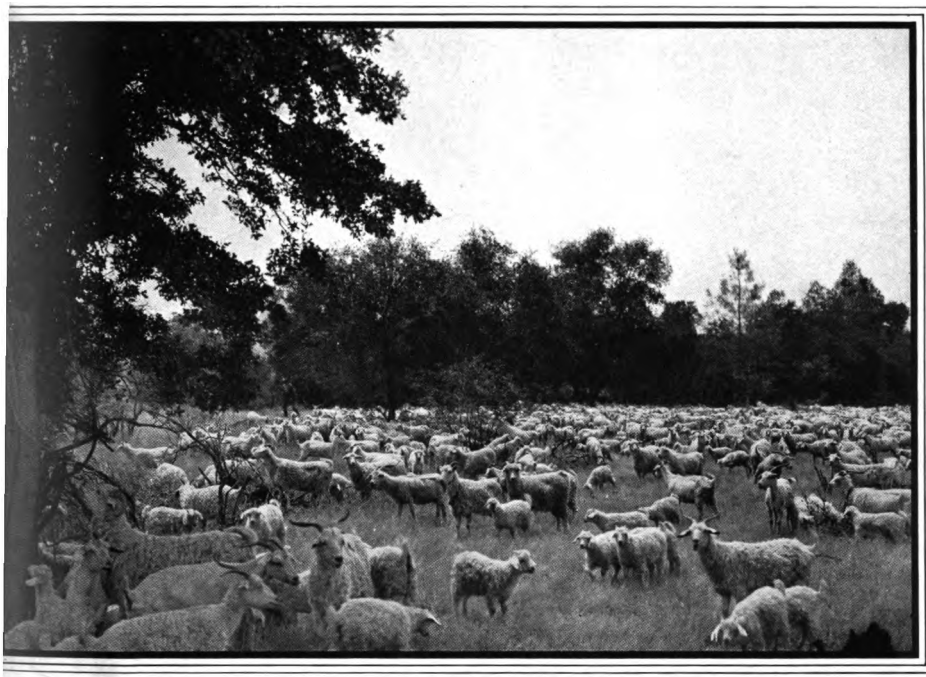

A HERD OF ANGORA GOATS.

A FIELD OF STRAWBERRIES IN HAPPY VALLEY DISTRICT.

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Molinos River, which streams drain the slopes of Mount Lassen. Nearly all of this project is fertile bottom land, which was sold in small tracts and has been developed largely as a dairy district, with alfalfa the predominant crop.

The Orland project, built by the Reclamation Service, lies on both sides of Stony Creek near Orland, and covers 20,000 acres. This project embraces a variety of soils, and is rapidly being developed as an alfalfa and fruit growing district. Water rights are expected to cost about $50 per acre, but have not been definitely fixed by the Government. The project is considered one of the most successful of Government projects.

The above three districts demonstrate clearly that irrigation of this part of California is regarded as desirable, and that lands irrigated are fertile and productive.

GENERAL QUESTIONS AFFECTING DIVERSIONS FROM SACRAMENTO RIVER AND TRIBUTARIES.

Navigability of the Sacramento River.—That portion of the Sacramento River below Red Bluff is considered a navigable stream. In the report by the United States Reclamation Service, dated November, 1914, on the Iron Canyon project, attention is directed to the fact that between Chico Landing and Sacramento the annual tonnage handled by river boats has averaged 120,000 tons of an aggregate annual value of $6,000,000, but that the tonnage handled between Red Bluff and Chico Landing had been relatively very light and constantly tending to decline.

One of the reasons for the insignificant river navigation above Chico Landing was that—

"the bad regimen of the river during recent years combined with the smaller available freight tonnage and lack of satisfactory shipping facilities have led to the practical abandonment of river navigation above Chico * * * and there is to-day no means whereby shippers can take advantage of river navigation here even should they so desire."

The report goes on to state:

"In spite of the poor showing that upper river navigation now presents, there is the possibility that under the large plans of reclamation of arid and bottom lands now proposed or in progress * * * and the flood-control project of the lower valley, the tonnage available for water carriage may be heavily increased during the next few years and upper river navigation thereby revived and placed on a higher plane of usefulness and prosperity."

Further, that—

"the relative importance of the waters of the Sacramento to transportation and to agricultural development in the Sacramento Valley is a question that should be decided by the State and Nation at the

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earliest possible date, in order that the various improvements proposed can be brought into harmony under a carefully devised policy."

The Débris Commission, in the report of August, 1910, to the Chief of Engineers, states as to existing navigation conditions:

"While entirely inadequate as a flood channel, the Sacramento River has a good navigable channel below Colusa. The following shows the low-water depths below Red Bluff, the head of navigation:

"Below Sacramento, 64 miles, 7 feet minimum depth.
"Sacramento to Colusa, 90 miles, 4 feet minimum depth.
"Colusa to Chico, 57 miles, 3 feet minimum depth.
"Chico to Red Bluff, 52 miles, 3 feet for about 6 months; 1½ to 2 feet for about 6 months."

Quoting again from the Iron Canyon report:

"Between Chico Landing and Red Bluff navigation has only been considered practicable at times of high water, from January to June. About $6,000 per annum has been expended in removing snags and building wing dams in this section. In 1910 the United States engineers estimated that a 3-foot channel for nine months in the year could be obtained at a first cost of $52,000, and an annual maintenance charge thereafter of $32,000.

"It will be seen from the above statements that river traffic above Chico Landing is almost negligible under present conditions, and even above Sacramento the tonnage is comparatively light.

"The flow of the Sacramento River at Red Bluff occasionally falls below 4,000 second-feet, and in a 19-year period of record, selecting the two driest months of each year, there is as follows:

"In 2 months out of 38 the average flow is less than 4,200 second-feet.
"In 3 months out of 38 the average flow is less than 4,400 second-feet.
"In 12 months out of 38 the average flow is less than 4,600 second-feet.
"In 14 months out of 38 the average flow is less than 4,800 second-feet.
"In 21 months out of 38 the average flow is less than 5,000 second-feet.

"Considering only these dry periods which happen also to coincide with the months when shipments from an agricultural and horticultural district would naturally be at a maximum, it can be deduced that:

"During 10 per cent of the low water period the flow will be less than 4,350 second-feet.
"During 20 per cent of the low water period the flow will be less than 4,550 second-feet.
"During 30 per cent of the low water period the flow will be less than 4,700 second-feet.
"During 40 per cent of the low water period the flow will be less than 4,830 second-feet.
"During 50 per cent of the low water period the flow will be less than 4,950 second-feet.
"During 60 per cent of the low water period the flow will be less than 5,070 second-feet.
"During 70 per cent of the low water period the flow will be less than 5,250 second-feet.
"During 80 per cent of the low water period the flow will be less than 5,450 second-feet.
"During 90 per cent of the low water period the flow will be less than 5,700 second-feet.
"During 100 per cent of the low water period the flow will be less than 6,100 second-feet.

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"The navigable channel below Red Bluff and above Chico Landing is in time of low-water flow both shallow and tortuous. This is inevitable in a channel that has a flood capacity of upward of 200,000 second-feet and a low-water flow of less than 5,000 second-feet."

That the conditions of navigability, or lack of navigability, between Chico Landing and Red Bluff are matters of live concern to the United States is shown by the fact that the river and harbor act approved March 4, 1915, has provided for a preliminary examination of the Sacramento between these points. An official communication signed by L. H. Rand, major, Corps of Engineers, and dated June 18, 1915, is as follows:

"[Circular letter.]

"ENGINEER OFFICE, UNITED STATES ARMY,
"*San Francisco, Cal., June 18, 1915.*

"The United States river and harbor act approved March 4, 1915, provided for a preliminary examination of Sacramento River from Chico Landing to Red Bluff.

"The established procedure in such cases is for the War Department, under whom the administration of this act falls, to assign, through the Chief of Engineers, United States Army, to the district officer in the locality the duty of preparing the report involved. The preliminary examination report does not go into any detail as to the *methods* of improvement. It is concerned solely with the probabilities as to the improvement being a profitable undertaking from a commercial viewpoint.

"The report of the preliminary examination covering this commercial phase of the matter, with a *general* physical description of the river and country involved, is submitted through the Chief of Engineers, United States Army, to the Secretary of War, and if, in their opinion, the proposition is one which promises favorable possibilities, a further report on a plan or plans of improvement, with estimated cost, based on such surveys as may be necessary, is directed to be made by the district officer. This office has been charged with the preparation of the above-named *preliminary examination* report.

"It is the policy of the War Department in such cases to accord as nearly as practicable, consistent with an economical administration of the national finances, with the desires of the local interests concerned and to allow the local interests to furnish all information which they may desire so to do looking toward the purposes in mind.

"Representatives of this office will later visit the territory in the outlined section of the river for the purpose of amplifying and verifying its information on the subject, and it may be that public hearings will be held at announced times and places to permit all concerned to express their views with the minimum inconvenience. To enable this matter to be handled most advantageously and at the minimum expense, it is, however, requested that all who care to do so submit definite information and their views in writing, in duplicate if practicable, to this office at the above address, at their earliest convenience. So far as possible vague generalities should be avoided—definite facts, industries that could be established or expanded by

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water transportation, or other benefits that would result in definite amount should be made known.

"It is not impossible that the improvement phases of this river, from the navigation point of view, may be in some way combined with irrigation, power, flood control, or similar matters, involving storage and regulated water discharge on the river. While views as to the desirability and feasibility of such are at all times welcome, that is not, however, the primary concern in this instance. It may later be more completely gone into in the subsequent report on the *plan* of improvement, if called for, but the present report deals primarily with the *commercial desirability* of a suitable improvement to permit navigation.

"At the present time the United States is committed to the improvement of this section of the river only to obtain such navigable conditions as the funds which Congress makes available annually, or less often, permit, and of recent years the funds made available have not permitted extensive work on this section of the river. It is believed that the conditions are well known to all those interested and need not be elaborated here.

"The mere call by Congress for the reports above outlined can not be taken as committing the Federal Government definitely in any way to further improvement here.

"L. H. RAND,
"*Major, Corps of Engineers.*"

It thus appears from the above that improvements of navigability of this portion of the stream will be considered in connection with irrigation, power, flood control, and other uses involving storage and regulated water discharge. As above shown, the low-water flow of the Sacramento below Red Bluff little exceeds 4,000 second-feet for a large proportion of the period of low flow, also that the minimum navigable depth during the low-water period is only from 1½ to 2 feet. It is therefore evident that any considerable diversion of low-water flow will seriously impair possibilities of future improvement in navigability unless some comprehensive plan of canalization be undertaken.

No definite data on the question of canalization, its value or its cost, are available. It may, however, be expected that the investigation now pending under the War Department will shed some light on this topic. Some approximate figures were, however, prepared in connection with the report on Iron Canyon project, appearing on pages 54 and 55 of said report. These indicate that canalization between Chico Landing and Colusa might possibly cost about $4,000,000, this covering a distance of 57 miles, with a total fall of 76 feet. Between Red Bluff and Chico Landing the river falls about 135 feet in 2 miles, or nearly double the fall between Chico Landing and Colusa. The cost of canalization may be expected to increase proportionately to the total fall, which will mean that canalization figured on the same basis as the above would be likely to cost $8,000,000 between Red Bluff and Chico Landing.

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Allowing a wide latitude for errors in these rough approximations, it is nevertheless clear that any scheme of canalization in this portion of the river will be so costly as to be prohibitive under present-day conditions.

If, however, it be granted that canalization is impracticable, it follows that any improvement of navigability must depend largely on the protection of the low-water flow and possibly even its supplement by storage; new diversions for irrigation without full compensation by storage would be inadmissible.

That the navigability of the Sacramento is considered of high importance is emphasized by statements of Federal and State officials of the United States California Débris Commission, the Flood Control Committee of California, and others, as quoted in the report on Iron Canyon project, pages 35 to 41, inclusive. The Débris Commission has recommended that to improve navigability of the Sacramento River the United States and the State of California each contribute toward a total fund of $11,717,000 for the construction of a system of by-passes, levees, weirs, and other structures to control and regulate floods. The general scheme of improvement recommended by the Federal and State officials comprehends deepening and straightening the navigable channels, minimizing the effects of floods by the by-pass system, and reclaiming large tracts of land in the basins adjacent to the lower reaches of the river, this work to be carried out under the State, subject to Federal approval of plans and construction.

It may be here stated that this general plan has been formally adopted by the State and is now in process of construction, a large part of it being already built. This development is of first-class magnitude, involving expenditures now estimated at not less than $40,000,000, and being undoubtedly one of the largest plans of improvement and development now under way in the West.

Irrigation diversion from navigable streams.—Much has been said and written recently about the relative importance of inland navigation in California and the preservation and protection of stream flow for navigation purposes.

In the report on the Iron Canyon project, page 15, appears the following statement regarding irrigation diversions adverse to navigation interests. Referring to various plans of development of the Iron Canyon project, some of which include provision for reservoirs to protect the navigability of the river during the low-water season, it states:

"Certain plans herein described assume as fundamental that the low-water flow of the Sacramento must be preserved for navigation purposes. This view may or may not be correct. Looking at the

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question solely from the irrigation standpoint it would appear that the irrigation of Iron Canyon project might be cheapened if the low-water flow, which seldom falls below 4,500 second-feet, could be freely drawn upon for irrigation without regard to navigation requirements or without making any provision for compensating storage.

"The United States, through the War Department, has jurisdiction over all matters affecting the navigability of rivers. It has, by act of Congress approved May 9, 1906, granted the Central Canal the right to take 900 second-feet from the river for irrigation when the river is 2 feet above low-water stage, but has reserved the right to stop all diversions when navigation interests are seriously injured thereby. Apparently the War Department has also in another case acquiesced in irrigation diversions at times when the river stage was 2 feet and over above low water, notably in the case of Mr. R. T. Stone, of Davis, Cal.

"The situation with regard to protecting navigability of the upper river is anomalous. Technically, it is not practicable to divert water from the river for irrigation or other purposes without injury to the navigability of the stream. Diversions are, however, being made on a large scale, and further diversions on a much larger scale are in contemplation. The State, as owner of public waters, freely acquiesces in these constantly increasing irrigation diversions, although it is fully understood that diverters, even when acting in full compliance with State law in matter of diversions and uses, are at times liable to be enjoined by the Federal authorities on the ground of interference with navigability. Diverters are therefore compelled to exist with this uncertainty as to their status impending. Enterprise necessarily suffers very seriously from these conditions, which militate principally against the larger propositions, which by their magnitude tend to invite Federal intervention that may be escaped by the less conspicuous enterprise."

A recent conspicuous case of a contemplated irrigation diversion adverse to navigation is in the organization of an irrigation district, known as the Anderson-Cottonwood district, that proposes to water some 30,000 acres of land south of the city of Redding by means of a direct diversion from the Sacramento River at Redding. This and other cases illustrate the chaotic condition of control, or, rather, lack of control, and the need for the formulation of a definite water policy for the Sacramento.

The board of review that considered the report on Iron Canyon project has enunciated the general principle that irrigation should be considered as paramount to navigation in the arid West, and has recommended that the run-off of the Sacramento should be used, as far as practicable, for irrigation irrespective of navigation.

The contention that irrigation should be considered paramount to navigation is true only in a limited sense. Should we ever be reduced to an absolute choice between using water for irrigation and

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the production of crops or its use as a mere means of transportation, there would not, of course, be any other decision possible than one giving the preference to irrigation. The problem is not, however, always presented in a definite shape, such as the above, and, as a matter of fact, the question is wholly one of economics, in which the cost of storage and the respective values of irrigation and navigation may be considered in each individual case.

With regard to the Lower Pit River project, the total use of water contemplated is about 164,000 acre-feet per annum, of which about 100,000 acre-feet can be drawn directly from the natural flow of the Pit River (without storage) without reducing the low-water flow of the Sacramento available for navigation south of Red Bluff below 4,750 second-feet, an amount that has been referred to in the Iron Canyon report as a reasonably safe provision for low-water navigability. The above figures have been based on the stream-flow records of 1912, which was a year of unusually scanty run-off. In such a year there would have been no need for drafts on storage up to the end of July. During the balance of the irrigation season, however, about 60,000 acre-feet would have to have been provided by storage under any plan designed to protect low-water navigability at Red Bluff down to 4,750 second-feet.

In order to provide 60,000 acre-feet storage to compensate the lower river on account of navigation, it is evident that some other site than the Sheep Rocks site must be developed. To obtain 60,000 acre-feet at Sheep Rocks above the level of the tunnel intake the dam would have to be built to elevation 980 or thereabouts and the water raised a total of 220 feet, which, of course, would be prohibitive.

Storage sites at Round Valley and Jess Valley on the upper Pit can be developed to about 40,000 acre-feet in each case, but these reservoirs will be required for the use of the lands along the upper Pit, as stated in the report on Pit River Basin, previously referred to.

It may be possible to develop storage on Clear Creek or Cottonwood Creek or some other tributary of the Sacramento above Red Bluff, but no cheap storage, if any, has been located. The reservoir proposed at the Iron Canyon, if built, might, however, be utilized for this purpose by building the dam at Iron Canyon some 3 feet higher than would otherwise be necessary. It is evident, however, that the cost of this storage would in any event be not less than $10 per acre-foot, or substantially an additional $10 per acre on the irrigated land of the project, a very serious matter, if required, for the reason that the cost of project development, without provision for storage, will be close to the permissible limit.

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SUMMARIZATION.

From the foregoing statements it appears that the project lands are potentially fertile, and conditions of climate, location, transportation, and availability of markets indicate with reasonable assurance a basis of successful agricultural development if a supply of water can be secured for the land at reasonable cost. It must, however, be remembered that other highly important considerations enter into any general plan such as this to an extent that may radically modify conclusions otherwise favorable. It is proposed in this chapter to deal briefly with some of these.

The estimated cost of building irrigation works, without any allowance for interest and including only first cost of the dam, tunnel, canals, and other works, is in round numbers $65 per acre.

The probable cost of clearing lands of brush and trees and otherwise preparing for the final preparation of the lands for water is about $25 an acre on the project as a whole.

The probable average cost of leveling, checking, furrowing, or otherwise preparing the land for distribution of water, is about $20.

The grand total of all of these that may be properly considered construction charges is, therefore, roughly, $110 per acre. This figure is a basic charge underlying all possible future improvement of the district, and must be reckoned with as such. It represents the sum to be spent before the land would be ready for seeding or planting. For a total area of 55,000 acres this charge means an aggregate expenditure of $6,050,000, this, as before stated, being without any allowance for interest.

Now, in the development of any project of magnitude like this expenditures are not made in a lump sum, nor are the construction of the irrigation works and the development of the lands accomplished during a single year. In this case, however, nothing in the way of agricultural development of the lands can be accomplished until the principal irrigation works are completed, including the dam, tunnel, and main canals. These include not less than $50 out of the total of $65 per acre of estimated expenditure for irrigation. Moreover, at least some of the laterals and sublaterals must also be built to enable even a part of the land to enjoy the fruits of the construction.

It therefore is evident that upward of 80 per cent of the total expense of irrigation works must be incurred before agricultural development can proceed. This heavy initial cost will necessarily handicap quite seriously the proposition as a whole, for obvious financial reasons.

If the dam and main canals cost upward of $3,000,000 to build, it is important that their construction, if undertaken, should be pushed with energy; also that, concurrently with the construction of the

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irrigation works, the operations of clearing the land of brush and timber and preparing it for water should be undertaken, in order that no time be lost in rendering the enterprise profitable as a whole.

Under the conditions that are imposed by nature and the limitations of settlement, many years must elapse, under the most favorable conditions, before the tract as a whole is settled and put in a productive condition. The construction work will take not less than three years—possibly even four years. The work of clearing trees and brush, if organized on the basis of construction work, might be completed within that period, as could also a large part of the preparation of the surface of the soil for water.

Planting, seeding, and care of orchard and fodder crops will require from one to five or six years in addition to the construction period, and during that time a great deal of miscellaneous development work, such as fencing, building, road work, and other details, must be carried out by the individual settler or the community. It is important, however, to understand from the start that the margin of profit in the development of this project, when regarded from the standpoint of increased land values, or what is generally understood by the term "unearned increment," is practically nonexistent. It does not appear possible to construct or develop the project by units of moderate size and cost in which the agricultural development could proceed more or less independently of the construction work and where heavy increases in prospective land values would be in evidence and could be anticipated.

In the case of this project it may be safely assumed that after the land has been cleared, prepared, and watered the cost of developing an orchard will not be greater here than in other parts of California. The average cost of planting and four years' care of a deciduous orchard should be about $90 per acre; if vegetables or berries are grown between the trees, this cost can in part be reduced by the early returns from the latter crops. The cost of planting and developing fodder crops will probably not exceed $10 per acre, with practically immediate returns.

While it is probable the greater part of this area will ultimately go into fruit, nuts, or olives, it is probably equally true that the exigencies caused by the necessity for early returns from the land to enable the accumulated charges to be met will tend to place a large part of the tract in fodders, at least during the early stages of development.

To enable a comprehensive view of the situation to be had it is assumed that expenditures for constructing the irrigation works and for clearing and preparing the land are borne directly by the land on the basis of borrowed capital at 5 per cent interest. This is a much

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lower rate than irrigation districts in California are able to borrow money for to-day, even under recent State legislation specially designed to favor the flotation of irrigation bonds; on the other hand, it is a higher rate than that at which the State or the Government can borrow.

Experience in irrigation development has established the fact that, in general, repayment of the capital investment in construction and early development of a project can not be made from agricultural returns during the early years. The nonproductive period necessarily varies with different localities, but in any event it is believed to be a safe statement that no substantial part of the investment for construction and land development for this project could be returned during the five years following the commencement of the project. This general statement takes full cognizance of the fact that under exceptional conditions a few small tracts here and there might begin to be on a paying basis before the expiration of the above period. If the settlers as a whole are able to get a substantial start in planting their land, building homes, fencing, and stocking their farms, besides paying the operating expenses of the canal system, it is as much as could be hoped and much more than could be reasonably expected, during the five-year period.

For purposes of illustration, a five-year period has been assumed for the project during which all initiatory stages of construction and development are supposed to have been completed at a total expenditure of capital of $6,050,000. Nothing is included in this total for buildings, planting, seeding, or other agricultural development; it is supposed that the investment has included only what is necessary to enable the settler to establish himself and start to cultivate the soil, without the necessity for pioneer work of clearing and grading which is sometimes left to individual initiative, but which conditions forbid in this case.

The probable investment year by year, interest being computed at 5 per cent, will be as follows:

Expenditures.

Year.	Construction.	Clearing and preparing.	Total.	Interest.
First	$825,000	.....	$825,000	$21,000
Second	1,100,000	$825,000	1,925,000	90,000
Third	1,100,000	825,000	1,925,000	191,000
Fourth	275,000	550,000	825,000	269,000
Fifth	275,000	275,000	550,000	317,000
Total	3,575,000	2,475,000	6,050,000	888,000

The total indebtedness will thus be $6,938,000, or $126 per acre.

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Even if the land be at once placed in alfalfa or other crops yielding immediate return the additional investment will bring the total up to about $140 per acre, without any allowance for buildings or other necessities. With the land placed in orchard the period of production is further deferred and interest charges will heavily accumulate, so that the aggregate indebtedness at the time the orchard comes into bearing will be high.

It is thus clear that the project must be thoroughly organized and rapidly developed to enable it to bear even so moderate a rate of interest as the above. It also is clearly shown that there is no opportunity for the landowner to exploit land values in anticipation of future development, for the reason that the margin of future profits is so small that it must necessarily wholly inure to the settler if he is to establish himself without an intolerable burden of debt.

Conclusions and recommendations.—That the project is not feasible as a private enterprise by reason of the diverse character of the ownership and the heavy initial investment necessary.

That the project, if found feasible after more detailed examination, must necessarily be built by the Government, the State, or possibly one or both of them acting in cooperation with the landowners.

That it will be necessary to include in the construction operations carried out by the central administrative organization not only the irrigation system but the clearing of the land and its preparation for water.

That the organization of the project must be such that it will be impossible for land to be withheld from utilization for purposes of speculation and that early and full agricultural development must be assured.

That the public interest warrants the withdrawal from entry or sale of any Government or State land embraced within the limits of the project or the works proposed for its use.

That the State and the Nation reach an understanding as to public policy to be followed in the utilization of the waters of the Sacramento River.

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